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WONDERS OF GEOLOGY;

OR

A Familiar Exposition of Geological Phenomena.

BY

GIDEON ALGERNON MANTELL, LL.D., F.R.S., F.G.S.,

Volcanic Island in the Mediterranean.—Page 875.

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BY T. RUPERT JONES, F.G.S.

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PREFACE TO VOL. II.

The few months that have elapsed since the preparation and publication of the 1st volume of this edition of Mantell's "Wonders of Geology" have been as productive of geological facts and theories as any such former period, if not more so. Most of the new discoveries in geology, and of the determination or correction of former hypotheses, have been described or commented upon in various communications published by the Geological Society of London; and many other points of geological interest have been treated of in papers read before the Geological Societies of Dublin, Paris, Berlin, and Vienna, or before other Scientific Societies of Europe and America.

Not to dwell upon the much-increased list of the planetoids (p. 44), to the known number of which seven have been already added,—or the additional recorded instances of aerolitic phenomena, but to refer to circumstances more closely connected with physical geology, we may draw attention to Sir C. Lyell's lucid résumé of facts relative to the secular elevation of the land,—of an abstract of a lecture on this subject not long since delivered, by the author of the "Principles," we have availed ourselves (p. 958). In another direction, our study of physical geology has of late been greatly aided by Mr. H. C. Sorby's remarkable researches in the microscopical structure of rocks, both sedimentary and hypogene, and of the component crystals of the latter (see p. 948). Mr. Prestwich's hypothetical extension of Upper Tertiary deposits over a great part of the South-east of England demands careful attention; and, though not yet clearly substantiated, and indeed still forming a geological problem difficult of solution, has already been productive of valuable results, in setting geologists at work again over a country once thought to have been nearly exhausted of geological novelties.

But perhaps the discovery of a large granitic boulder in the heart of the Chalk of Croydon (p. 972) has been as prolific a source of geologic argument and romance as any fact lately brought forward. The outlines of the old cretaceous ocean and its archipelagos,—its shores and sea-deeps, its sea-weeds and drifted shells,—the jungles of its coasts,—and the possible icebergs of its northern limits,—offer a wide field both for the strict physicist and the imaginative geologist. With this subject is closely connected the probable existence in the early part of the Cretaceous period of a ridge of rocks, chiefly belonging to the coal-measures, ranging across the South British area, as explained and illustrated of late by Mr. Godwin-Austen (see p. 756, *note*). The presence of this old ridge in the cretaceous ocean has had two important results. In the first place it gave rise to local shingly deposits, interrupting the general succession of the sands and clays older than the Gault, and has thereby rendered it unlikely that we shall be able to obtain from beneath London such a supply of water, by means of very deep Artesian wells, as has been obtained at Grenelle from the Lower Greensand; and, secondly, it has probably borne up, as a part of its constituent mass, some coal-beds, continuous with those of Belgium on one hand, and of Somersetshire on the other; thereby *possibly* affording coal in deep borings, in this district.

In the study of fossils, so many new and interesting facts have been elucidated, that we can only refer to a few: such as Mr. Beckles's further discoveries among the Mammalia and Reptilia of the Purbeck period, and his discovery of the bones of the entire foot of the Iguanodon, which, being *three-toed, may* well fit some of the fossil foot-marks described at p. 383, as having been found in deposits formed among the haunts of this great reptile;—to the descriptions, by Prof. Huxley and Mr. Kirkby, of Crustaceans of higher rank than Entomostraca in the Permian and Carboniferous deposits;—to the discovery, by the geologists of Ludlow and the neighbourhood, of many more fish-remains in the Upper Silurian than had hitherto been known;—and especially to Dr. Falconer's luminous exposition of the zoological and geological relations of the true species of Mastodon and Elephant (see p. 963).

To the results of Sir R. I. Murchison's well-sustained researches among palæozoic rocks and fossils we owe very much indeed that is new in our knowledge of the Permian and Silurian formations. Of the latter especially we have a recently corrected classification, which, elaborated by this distinguished geologist, and enriched by the labours of American, European, and British palæontologists, is, with Sir Roderick's kind permission, brought forward in this little work for the use of the student, even before its appearance in the forthcoming Second Edition of Sir R. Murchison's "Siluria." Last, not least, we must particularly notice the disentanglement of the ravelled clue to a clear knowledge of the relations of the rocks of Sutherlandshire, where Mr. Peach's late discovery of an important set of fossils in a band of altered limestone has enabled Sir R. Murchison to bring to their true bearings the observations made in this locality by himself and others, and not only to rectify errors and to disperse the obscurity which covered the geological history of the North-western Highlands of Scotland, but to place enormous masses of the stratified rocks of this region into their right places in the geological scale, and in relation with their equivalent formations in Scandinavia, Canada, Wales, and elsewhere.

T. Rupert Jones.

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1. Zoology of the Chalk.—The examination of the Cretaceous and Wealden formations has afforded an instructive exposition not only of the nature of oceanic and fluviatile deposits in general, but also of the condition of animated nature at the close of the geological cycle which comprises the secondary epochs. It will therefore be expedient in this stage of our inquiry to consider the general features of the animal kingdom during the periods embraced in this review.

In the ocean-bed of the cretaceous period, we find vestiges of all the principal groups of existing marine organisms; comprising many genera of the Shark-family—viz. species of Cestracion, Lamna, Corax, &c.; with fishes related to the Chimæra, Salmon, Mackerel, Basse, &c.;—in fact, the leading types of the majority of the fishes that inhabit the present seas.* The Cephalopoda (Cuttle-fishes) and Echinodermata (Sea-urchins, Star-fishes, and Encrinites) were profusely developed; crustaceans allied to the Hermit-crab, Lobster, Water-flea, &c.; univalve and bivalve mollusca; and innumerable multitudes of Sponges, Bryozoa, and Foraminifera;—all these forms of animal existence have left enduring memorials of their presence in the seas of those remote ages. And, although we have likewise proof that numerous extinct genera, together with others now of excessive rarity, swarmed in prodigious numbers in the cretaceous ocean, and negative evidence that the Cetacea (see above, p. 325), as the Whale, Porpoise, Seal, &c., were not among its inhabitants, yet the diversified types of animated beings whose relics are entombed in these strata show that the waters of the deep possessed the same general conditions, and maintained the same relations with the atmosphere and with light, as at the present time.

The most remarkable peculiarity in the zoological features of the Chalk relates to the abundance of marine Reptiles; for, with the single exception of a lizard belonging to the family of the *Iguanidæ*, which inhabits certain parts of the sea-coasts of South America,† the Chelonians or Turtles are the only known existing marine animals of this class. But the cretaceous sea was tenanted by several Saurians of con-

* See the chronological table in M. Agassiz's Recherches sur les Poissons Fossiles, tome i.; and Morris, Catal. Brit. Foss. p. 316, &c.

† The *Amblyrhynchus cristatus* of the Galapagos Islands: see Mr. Darwin's Journal, in the Colonial Library, p. 385; and Lyell's Manual, p. 326.

siderable magnitude,—namely, the Mosasaurus (p. 319), Polyptychodon (p. 367), Ichthyosaurus, Plesiosaurus; and by others of smaller size, such as small Turtles and the eel-like Dolichosaurus.

Of the terrestrial fauna and flora, the evidence to be derived from deep-sea deposits must of course be scanty. We have, however, proof that the then dry land bore forests of pines; that ferns and plants of the cycadeous tribes formed the prevailing vegetation; and that the country was inhabited by Iguanodons, Pterodactyles, and other reptiles.

2. Zoology of the Wealden.—From data of a like nature, we learn that during the deposition of the Wealden there was an extensive region traversed by streams and rivers swarming with fishes, crustaceans, and mollusca, of extinct species, but belonging to the same principal types as those which inhabit the fresh waters of warm climates under similar conditions: and that then, as now, marsh-tortoises and crocodilian reptiles tenanted the swamps and lagoons.

Of the inhabitants of the land, we have more ample information from the relics ingulfed in the deltas and lacustrine sediments, than could be afforded by deposits accumulated in the depths of the ocean, and far from the regions whence they were derived.

Colossal herbivorous and carnivorous lizards, differing essentially in their organization from all existing reptiles, and of which no vestiges have been discovered in any strata newer than the Chalk, were the principal terrestrial vertebrata of the Wealden epoch. These, together with some small mammals, a few flying reptiles, and lizards of small size, and probably some wading birds, appear to have constituted the entire vertebrate fauna of the regions which furnished the materials of this formation. The flora consisted chiefly of ferns, coniferous trees, cycadeous plants, cypresses, and a few unknown, but apparently related forms.

In fact, the islands and continents of the late Oolitic and early Cretaceous epochs, during which time the Wealden deposits were being formed, appear to have possessed many similar zoological and botanical characters. Here then we have the first glimpse of extensive regions almost exclusively inhabited by enormous reptiles: for, though the leaves and fruits of delicate plants, the fragile bones of birds and flying reptiles, the wings of insects, and the brittle shells of molluscs with their ligaments and epidermis remaining, are abundantly found imbedded in the sediments of the rivers and seas, but few traces of mammiferous animals, and those of small size,* have been discovered in the Wealden deposits. We have now approached the *Age of Reptiles*;—that geological epoch, in which the earth swarmed with enormous oviparous quadrupeds, and the air and the waters alike teemed with reptilian forms.

3. SITE OF THE COUNTRY OF THE IGUANODON.—Before we pass to the investigation of the older secondary formations, I would briefly reconsider the question as to the geographical position of the principal tracts of country during the deposition of the Wealden and Cretaceous strata;—whether England was then dry land, and enjoyed a tropical climate; and whether turtles, crocodiles, and gigantic lizards here flourished amid groves of tree-ferns, and other productions of intertropical climes; or, on the contrary, whether the country of the Iguanodon was situated far distant from the area now covered by its spoils?

The unequivocal marks of transport which, as we have seen, the fossils of the Wealden so generally exhibit, seem to demonstrate that the reptiles and terrestrial plants could not have lived and died in the regions where their relics are imbedded: for, with the exception of the beds of river-shells and minute crustaceans, and the plants which indicate a

* The Spalacothere and Plagiaulax, and their allies, in the Purbeck series.

lacustrine condition, the organic remains frequently bear indisputable marks of having been transported from some remote country, by a river or powerful flood of fresh-water.*

The specimen of the Hylæosaurus (*ante*, p. 449) throws light on this question. Many of the vertebræ and ribs are broken and splintered, but the fragments remain near each other: and, though the bones are more or less displaced, yet they lie in situations bearing some relation to their natural positions. These facts demonstrate that the carcass of the animal must have been contused and mutilated, and that the dislocated and broken parts were held together by the muscles and integuments. In this state the headless trunk must have floated down the river, and at length have sunk into the mud of the delta, where is formed a nucleus, around which the stems and foliage of ferns and cycadeous plants accumulated, and river-shells became intermingled in the general mass. Here then we have evidence of the body of a terrestrial reptile having been transported from a considerable distance by a stream or current of fresh water; for not the slightest indication of marine detritus can be traced in the deposits in which it was imbedded. The country where this animal lived and died may therefore have been situated far from the spot where its fossil remains were entombed.

An eminent geologist † has the following remarks on this subject:—

"If it be asked where the continent was placed from the ruins of which the Wealden strata were derived, and by the drainage of which a great river was fed, we are half tempted to speculate on the former existence of the Atlantis of Plato. The story of the submergence of an ancient continent, however fabulous in history, may be true as a geological event. Its disappearance may have been gradual; and we need

* The upright trees of the Isle of Portland present an exception; but this forest may have grown on an island very remote from the mainland, inhabited by colossal reptiles.

† *Lyell; Elements of Geology*, Second Edition, vol. i. p. 432.

not suppose that the rate of subsidence was hastened at the period when the displacement of a great body of fresh water by the Cretaceous sea took place. Suppose the mean height of land drained by the river of the Wealden estuary to have been no more than 800 or 1000 feet; in that case, all except the tops of the mountains would be covered as soon as the fundamental Oolite and the dirt-bed were sunk down about 1000 feet below the level which they occupied when the forest of Portland was growing. Towards the close of the period of this subsidence, both the sea would encroach and the river diminish in volume more rapidly; yet in such a manner, that we may easily conceive the sediment at first washed into the advancing sea to have resembled that previously deposited by the river in the estuary. In fact, the upper beds of the Wealden, and the inferior strata of the Lower Greensand, are not only conformable,* but of similar mineral composition.

"It is also a remarkable fact, that the same *Iguanodon Mantelli* which is so conspicuous a fossil in the Wealden has been discovered near Maidstone, in the overlying Kentish-rag, or marine limestone of the Lower Greensand. Hence we may infer, that some of the Saurians which inhabited the country of the great river continued to live when part of the country had become submerged beneath the sea. Thus in our own times, we may suppose the bones of alligators to be frequently entombed in recent fresh-water strata in the delta of the Ganges; but, if part of that delta should sink down so as to be covered by the sea, marine formations might begin to accumulate in the same space where fresh-water beds had previously been formed; and yet the Ganges might still pour down its turbid waters in the same direction, and transport the carcasses* of the same species of alligator to the sea; in which case their bones might be included in marine as well as in subjacent fresh-water strata."

4. Lithological structure of the Iguanodon country.—The nature of the rocks and strata of which the country of the Iguanodon † was composed is also a subject of considerable interest; and from the first moment that the fluviatile origin of the Wealden suggested itself to my mind, to the time when I was compelled by ill health to quit the field of my early researches, I lost no opportunity of obtaining data by which the problem might be solved, and carefully examined the pebbles and boulders, and the fine

* The Rev. C. Fisher points out the exceptional unconformability of these deposits in Dorsetshire. Trans. Camb. Phil. Soc. vol. ix. p. 556.

† See also *Petrifactions* and their Teachings, chap. 3.

detritus as well as the coarser materials of which the Wealden beds are composed.

My lamented friend, the late Mr. Bakewell, kindly afforded me his valuable aid in determining the nature of the rocks whence the debris was derived; but the materials were too scanty to throw any satisfactory light upon the inquiry. In the "Fossils of Tilgate Forest," a bed of conglomerate, near Cuckfield, is described as containing pebbles of white, yellow, pink, and mottled quartz, jasper, flinty-slate, and indurated sandstone: and from this deposit I expected to obtain more satisfactory information than from the fine detritus of which the sands, sandstones, and clays consist. But with the exception of small pebbles of rock-crystal,* the substances above mentioned comprise all the transported minerals that have come under my observation. The abundance of micaceous particles in many of the sands and sandstones, and the prevalence of argillaceous and arenaceous deposits, seem to indicate a region in which were primary rocks, with sandstones and clay; for the quartz-pebbles and the micaceous sands and clays may have been derived from decomposed granitic and felspathic rocks. Extraneous fossils are rare both in the Wealden and the Chalk.† Debris of oolitic fossils, however, occur in some beds of the Lower Greensand in Surrey.

The observations of Dr. Buckland on this problem entirely accord with the result of my own investigations.

"The general absence of pebbles shows that the lands were distant

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* Small rock-crystals are often found in the sandstone near Tunbridge Wells, and are cut and set in rings and brooches by the lapidaries of that town.

† A rolled fragment of coniferous wood, which, from its state of mineralization, there is reason to conclude is from the Oolite, was found by Henry Carr, Esq., in a block of white chalk from a railway-cutting near Epsom. See Geology of the Isle of Wight, p. 140. Dr. Fitton mentions *having found a rolled* ammonite in the Wealden.

from whence the fine particles of sand and clay were transported. . . . . We should be inclined to look for these lands either in Devonshire or Cornwall, on the west; or in the nearest primary and transition mountains of the Continent, viz. in Normandy and Brittany, on the south-west; or in the forest of Ardennes, on the south-east. It is not probable that the materials of the Wealden formation have been derived in any great degree from the detritus of the Oolitic series, because in such case we should have found among them an admixture of pebbles of Oolite, none of which have yet been noticed."*

Of the seaward extension of the delta of the Iguanodon river, no certain indications have yet been obtained: † but it is evident that there must have been intercalations of the detritus and organic remains of the land and fresh-water with those of the sea into which the mighty stream discharged its waters; and there can be no doubt that sooner or later such fluvio-marine Wealden strata as those at Punfield and at Beauvais, when studied more extensively, will be found to throw much light on the history of the Wealden.

5. LOWER SECONDARY FORMATIONS. — In accordance with the chronological arrangement (p. 202), I proceed to the consideration of the antecedent, or lower, group of the secondary formations, namely the *Oolite*,‡ *Lias*, and *Trias*. As a whole, the series consists of alternations of clays, marls, limestones, sands, and sandstones, abounding in marine exuviæ, and which have evidently been deposited in the basin of a sea or seas. With these strata are intercalated in some localities beds of fluvio-marine detritus, in

* Geol. Trans. 2nd series, vol. iii. p. 430.

† Mr. Godwin Austen's Map, Pl. I., vol. xii. Geol. Soc. Journ., and his observations, *op. cit.* p. 66, should be consulted on this subject.

‡ The Oolitic and Liassic rocks may be conveniently considered under the single term "Oolitic," or, still better "Jurassics." As the Jura mountain-range comprises the whole series of these rocks, the continental geologists, dividing them into groups, know them as the "White (or Upper) Jura," "Brown (or Middle) Jura," and "Black (or Lower) Jura," and collectively as the "Jurassic formation."

which vestiges of terrestrial animals and plants are imbedded.

(I shall also comprise in this Lecture a notice of the *Permian* formation, although belonging to the palæozoic system, because the mineral and some of the organic characters are conveniently described when treating of the Trias, and that the Carboniferous system may be considered in a separate discourse.)

The fossil remains of the inhabitants of the Jurassic sea comprise a prodigious number of foraminifera, zoophytes, echinodermata, mollusca, crustacea, fishes, and reptiles, nearly all of extinct forms. The fossil marine plants of this series belong to several species of algæ; and those of the land consist of such as were transported into the ocean by rivers and currents, namely, trunks and branches of coniferous trees, cycadeous plants, ferns, &c.; sometimes occurring in the state of lignite and coal. The relics of the land animals are principally of insects, with bones and teeth of numerous reptiles; and of three genera of small *terrestrial mammalia*. Evidence is thus afforded of the existence of countries clothed with a luxuriant vegetation, and inhabited by numerous reptiles and a few warm-blooded quadrupeds.

6. General view of the Oolite and Lias, or the Jurassic formation.—This formation may be described as consisting of three principal argillaceous and of an equal number of calcareous deposits; namely, Upper or Portland Oolite, and the Kimmeridge Clay; Middle or Coralline Oolite, and Oxford Clay; and Lower Oolites, and the Liassic Clays. The leading subdivisions of these strata, as they occur in England, and the names by which they are generally distinguished, are expressed in the following table. The Lias is included; for, though, in conformity with the usual geological classifications, this group of strata is placed as a separate formation in the synopsis (p. 202), we shall find it convenient, *and, I believe*, more in accordance with

the origin and nature of the deposits, to comprise it in a general survey of the Oolitic or Jurassic series.*

THE OOLITIC OR JURASSIC GROUP.

OOLITE.

UPPER OOLITE of the Isle of Portland, Wilts, Bucks, Berks, Oxfordshire, &c.	1. *Portland Stone*, and *Portland Sand*;—limestone, usually white, with layers of cherty flint; green and ferruginous sands: *Ammonites*, *Terebræ*, *Trigoniæ*, with other marine exuviæ; some bones of reptiles, and drifted wood. 2. *Kimmeridge Clay*;—blue clay, with septaria, bands of sandy concretion, and bituminous shale; marine reptiles, fishes, shells, corals, and other organic remains.
MIDDLE OOLITE. Wilts, Oxfordshire, Yorkshire.	1. *Calcareous Grit* and *Coral-rag*;—sandy limestone, shell-limestone, and limestone composed of corals, with shells and echini. 2. *Oxford Clay*;—blue clay, with septaria; abounding in fossils: a ferruginous sandy limestone, called *Kelloways-rock*, full of shells, is subordinate to this clay.
LOWER OOLITE. Wilts, Somerset, Gloucestershire, Oxfordshire, and Northamptonshire.	1. *Cornbrash*;—coarse shelly limestone, with clay. 2. *Forest Marble*, and *Bradford Clay*;—fissile arenaceous limestone, coarse shelly oolite, sand, grit, and clays. 3. *Great Oolite*;—Oolitic limestone and calcareous freestone; sometimes rich in shells. *Stonesfield slate*;—fissile oolitic limestone, containing remains of coniferæ, cycadeæ, ferns, and algæ, marine shells and fishes; insects, reptiles, and *mammalia*. 4. *Fuller's Earth*;—marls and clays, with fuller's earth, and sandy limestones with shells. 5. *Cheltenham* or *Inferior Oolite*;—coarse limestone, with masses of trigoniæ, gryphææ, and terebratulæ; freestone and pea-grit;—ferruginous sand, with concretionary blocks of sandy limestone.

* In the Map, Pl. I. vol. i., the Oolite and Lias are denoted by the same colour and number (4).

LOWER OOLITE of the Yorkshire coast.	1. *Cornbrash*; a thin bed of rubbly limestone; which in many parts is a mere aggregation of shells and other fossils. 2. *Sandstones and Clays*, with land-plants; *thin coal and shale*; calcareous sandstone and shelly limestone (*Great Oolite*). 3. *Sandstone*, often carbonaceous with clays, full of leaves of terrestrial plants; *beds of coal* and *ironstone*. 4. *Limestone*, ferruginous and concretionary sands.
LOWER OOLITE of Brora in Scotland.	1. *Shelly limestones*;—alternations of sandstones, shales, and ironstone; with plants. 2. *Ferruginous limestone*, with carbonized wood, leaves, shells, and cypridæ. 3. *Sandstone and shale*, with *two beds of coal*.

LIAS.

LIAS of Dorsetshire, Somersetshire, Gloucestershire, Northamptonshire, and Yorkshire.	1. *Upper Lias shales and limestone* (*Alum-shale* of Yorkshire), replete with remains of fishes; reptiles, especially Ichthyosauri and Plesiosauri; Crinoidea in profusion; Crustacea; belemnites, ammonites, &c.; jet at Whitby. 2. *Marlstone*—calcareous, sandy, and ferruginous strata, rich in belemnites, ammonites, pectens, and other fossil shells; wood, ferns, and cycadeous plants. 3. *Lower Lias shales and limestones*—abounding in shells, *Plagiostoma giganteum*, *Gryphæa incurva*, &c.

This list, extensive as it appears, exhibits only the principal deposits comprised in the Oolitic system. The difference observable between the lower beds of the Oolites of the South-western counties and those of Yorkshire and Scotland, in the presence of accumulations of vegetable matter in the state of coal, with the remains of terrestrial plants,—and the occurrence of the relics of Zamiæ, Insects, Reptiles, and *Mammalia, in the Stonesfield* slate, are of great interest, for they attest the existence of land, and the action of rivers and currents. Our previous observations on the nature of oceanic deposits (vol. i. p. 57) will have prepared the intelligent reader for such intercalations of terrestrial detritus with remains of land-animals in the deposits of the ancient seas.

7. OOLITE OR ROE-STONE.—The limestones of this formation have very generally a peculiar structure, being composed of an aggregation of small rounded grains or spherules, presenting some resemblance to clusters of small eggs, or the roes of fishes; whence the name *Oolite*, or *Roe-stone*, which is now applied, not only to limestones possessing this character, but also to the entire series of deposits which intervene between the Chalk and Wealden above and the Lias below. On the Continent the group is generally termed "*Terrains Jurassiques*," from the Jura Mountains that divide France from Switzerland being largely composed of these deposits.

The oolitic structure is not however confined to this division of the secondary rocks; for it occurs in recent, in tertiary, and also in some of the most ancient sedimentary strata. It consists of an aggregation of grains or globules of calcareous matter, composed of concentric laminæ which commonly have a particle of sand, a minute shell, or a fragment of shell or other organic substance, as a nucleus. These globules owe their formation to the deposition of successive spheroidal concretions around the included body while subjected to the action of water in which a rotatory motion is induced; and the spheroids continue to increase until they become too heavy for further transport, and then subside, and are consolidated by subsequent infiltration. When the individual spheres are of a large size, the aggregated mass is called *pisolite* or peastone. The springs near *Carlsbad deposit* a beautiful conglomerate of this kind, some masses of which are sufficiently compact to admit of being manufactured into boxes and other ornaments. Polished slices exhibit every variety of sections of the concentric layers of which the concretions are composed; and, as the colour varies from a pure white to a delicate brown, the surface is elegantly marked with zones of various tints.

8. Geographical distribution of the Oolite.—The strata above enumerated form a striking feature in the physical geography of England, from the southern shore of Dorsetshire to the Yorkshire coast. They constitute a table-land of considerable elevation, the greatest heights amounting to 1500 feet, which extends in a tortuous line from the Dorsetshire coast, through Somersetshire, Wiltshire, Gloucestershire, Oxfordshire, Northamptonshire, and Lincolnshire, to the eastern shores of Yorkshire. This tract generally presents a bold escarpment to the west, and slopes gradually to the east, dividing the eastern and western drainage of that part of England.*

Certain subdivisions of the Oolite predominate in particular localities; thus, the Oxford Clay prevails in the midland counties,—the grey rubbly limestone, called Cornbrash, at Malmsbury, Chippenham, &c.,—the Forest Marble, in Oxfordshire and Somersetshire,—the Great Oolite, at Bath,—the Stonesfield Slate, or rather Tilestone, near Woodstock,—and the Inferior Oolite, in the Cotteswold hills.

The Lias forms a district that lies parallel with the escarpment of the Oolite, from beneath the base of which it emerges; it traverses the country from the well-known cliffs at Lyme Regis in Dorsetshire to near Redcar, on the Yorkshire coast.†

On the Continent the Oolite appears in Normandy, and its characteristic fossils prevail in the quarries around Caen; diverging into several branches or ranges of hills, it tra-

* See Geology of Yorkshire, by Professor Phillips.

† *The Western boundary* of the Oolites is shown on Mr. Godwin *Austen's map, Geol. Journ.* vol. xii. pl. 1.

verses France, forms the chief feature of the Jura Mountains, and constitutes part of the Alps; and in the latter, strata belonging to this system appear greatly altered in their mineralogical composition from the effect of metamorphic action. The Jurassic series of Germany,* contains the lithographic stones of Pappenheim, Solenhofen, and Mannheim, some beds of which are celebrated for the beauty and variety of their fossil remains.

Jurassic rocks occur in Spain, Algeria, Sicily, Italy, Croatia, and the Carpathians; also in Russia, the Crimea, the Caucasus, Persia, and Syria. Jurassic fossils have been collected in Cutch,† in the Himalayas,‡ in Central India,§ in South Africa,‖ and to a small extent in North America.¶ The eastern coal-fields of Virginia are referred by some geologists to the Jurassic period. Oolitic fossils are also stated to have been discovered in South America.

9. RAILWAY-SECTIONS.—In a previous Lecture (vol. i. p. 373) we described the sections presented by the South-Eastern railway as affording a coup-d'œil of the geological structure of that part of England: in like manner the lines that traverse our island in other directions enable the instructed observer to obtain a general idea of the geographical distribution and position of the principal groups of the rocks and strata.

More than a quarter of a century since, the information to be derived from such a survey was admirably pointed out by Conybeare.** "If," observes that eminent geologist, "we suppose an intelligent traveller taking his departure

* For a comparative view of the Continental and the English Oolites, see Fraas, Quart. Geol. Soc. Journ. vol. vii. part 2, p. 42; and Oppel, Wirtemberg Nat. Hist. Soc. Journal, 1857.

† Geol. Trans. 2 ser. vol. v. p. 297.

‡ Geol. Soc. Journ. vol. vii. p. 306.

§ *Ibid.* vol. x. p. 372, and xi. p. 376.

‖ Geol. Trans. 2 ser. vol. vii. p. 193.

¶ By M. Jules Marcou.

** Geology of England and Wales, p. ii.

from the metropolis, to make from that point several successive journeys to various parts of this island, for instance, to South Wales or to North Wales, or to Cumberland or to Northumberland, he cannot fail to notice (if he pays any attention to the physical geography of the country through which he passes) that, before he arrives at the districts in which coal is found, he will first pass a tract of clay and sand; then another of chalk; that he will next observe numerous quarries of the calcareous freestone used in architecture; that he will afterwards pass a broad zone of red marly sand; and beyond this will find himself in the midst of coal-mines and iron-furnaces. This order he will find to be invariably the same, whichever of the routes above indicated he pursues; and, if he proceeds further, he will perceive that near the limits of the coal-fields he will generally observe hills of the same kind of compact limestone, affording grey and dark marbles, and abounding in mines of lead and zinc; and at a yet greater distance mountainous tracts in which roofing-slate abounds, and the mines are yet more valuable; and lastly, he will often find, surrounded by these slaty tracts, central groups of granitic rocks."

The Great Western Railway, from London to Bath, and the Birmingham line from Euston Square to Derby, respectively traverse the strata comprised in the oolitic system; for our present purpose the former will afford the most instructive illustration. From the Paddington station, which is situated on London Clay (p. 232), the line passes along tertiary strata, by Ealing, Hanwell, and Slough, and enters the Chalk near Maidenhead; beyond Wallingford it traverses the clays and limestones of the Oolite, and the cuttings in many places exhibit good sections of these deposits. Near Bath it emerges on the Lias; and, crossing a narrow belt of Triassic strata, passes on to the Carboniferous beds of the Bristol coal-measures. In this route there are several localities of considerable *interest*, as Farringdon, Swindon, Chippenham, Calne, &c., to which we shall allude hereafter.*

10. SUBDIVISION OF THE OOLITE:—PORTLAND OOLITE.† —Beds of limestone having the roe-like structure above described form a principal lithological feature of the calcareous portion of the Oolite; but the uppermost deposits consist of shelly freestones, of variable structure. From the great employment of certain beds of this stone for architectural purposes, and the extensive quarries that have for centuries been worked in the Isle of Portland, this upper group is called the Portland stone. In the south of England, as we have already had occasion to mention (p. 397),‡ the Portland beds are covered by the Purbeck (Wealden) strata, including in some places layers of vegetable mould and petrified upright trunks of coniferous trees. The lower part of this group is composed of a bed of sand (*Portland sand*) from 50 to 80 feet thick, which gradually passes into the underlying clay. The fossils of the Portland beds are very numerous; large ammonites, pleurotomariæ, cerithia, trigoniæ, pectens, oysters, &c., and bones of saurians, with drifted coniferous wood, are among the prevailing organic remains.§

* See Medals of Creation, vol. ii.; Geological Excursions to Clifton, p. 864; and, for the section exposed by the Birmingham and Derby line, Excursions to Matlock, p. 867.

Mr. Hugh Miller contrasts the appearance of these railway-sections, in which the strata have a low angle of inclination (as usual with the secondary rocks of England), with those of the line from Glasgow to Edinburgh. There every few hundred yards in the line brings the traveller to a trap-rock, against which the strata are tilted at every possible angle of elevation. See "First Impressions of England and its People."

† For details of the geological phenomena exhibited by the beds below the Chalk and above the New Red Sandstone, in the south-east of England, Dr. Fitton's elaborate memoir, in the Geol. Trans. second series, vol. iv., should be consulted.

‡ See also Geological Excursions round the Isle of Wight, &c. p. 286.

§ As a British locality exhibiting the Portland strata and their cha-

11. The Kimmeridge Clay.—This argillaceous deposit consists of dark-bluish and grey clay, which in some parts passes into highly bituminous shale, known as "Kimmeridge Coal;" the name is derived from Kimmeridge in Dorsetshire, where some of the layers are sufficiently combustible to be used as fuel.* This deposit is in some places 300 feet in thickness, but thins out very considerably in the northern counties of England. It extends into France and Switzerland.

Near Hartwell, in the vale of Aylesbury, in Buckinghamshire, this clay is largely developed, and abounds in organic remains of great beauty and interest, especially Ammonites, Pleurotomariæ, Thraciæ, Pernæ, &c.; the nacreous or pearly coat of the shells of the ammonites is often as perfect and splendid with iridescent colours as in a polished shell of a recent nautilus. Many of the shells of which casts only occur in the Portland rock above are found preserved entire in the clay. A flat oyster of a deltoid form (*Ostræa deltoidea*) is very abundant, and is characteristic of the Kimmeridge clay.

Bones of Ichthyosauri, Plesiosauri, and Cetiosauri are occasionally found, also scales, teeth, and other remains of fishes, among which are mandibles of the Chimæroids.†

12. The Oxford Oolite, or Coral-rag.—The Kimmeridge clay rests on beds of coralline limestone, termed *Coral-rag*, many of which are really petrified coral-reefs, and

racteristic fossils, Swindon in Wiltshire is one of the most interesting. See Geological Excursions in the Medals of Creation, vol. ii. p. 862.

* See Excursions round the Isle of Wight, p. 265. This bituminous shale contains, according to the analyses of some chemists, 25 per cent. more illuminating power than Newcastle coal, when applied to manufacturing purposes. It occurs in several layers, varying from 2 to 7 feet in thickness, interstratified with dark-coloured sandy calcareous beds.

† The extensive Museum of Dr. Lee of Hartwell contains a fine collection of fossils from this neighbourhood; and strangers are allowed free access by the learned and liberal proprietor.

consist of coarse limestone, composed of stony corals, chiefly of the *Astræidæ* family, and having the interstices filled up

LIGN. 117.—SHELLS AND ECHINITE FROM THE OOLITE AND LIAS.

Fig. 1. Trigonia clavellata; from the Kimmeridge Clay.
2. ————————; a limestone-cast, from Portland.
3. Cidaris Blumenbachii; Coralline Oolite, Calne.
4. Trigonia costata; middle Oolite, Highworth, Wilts.
5. Spine of Cidaris Blumenbachii.
6. Gryphæa incurva; Lias. Cheltenham.
7. Ammonites bifrons (Walcottii, *Sow.*); Lias near Bath.

with shells, echinoderms, sand, and pebbles; the whole is more or less consolidated by calcareous, and in some instances by silicious, infiltrations. So obvious is the origin of these rocks, that the most incurious observer who travels through the districts where these deposits prevail cannot fail to remark the blocks of coral which everywhere meet his view in the quarries and on the road-side. In many parts of Wiltshire, Berkshire, and Gloucestershire, the Coral-rag is extremely rich in organic remains; corals, shells, and echinites occurring in almost every mass of stone. From the pits near Farringdon * hundreds of specimens may be collected in the course of a few hours; and the quarries near Calne, in Wiltshire, abound in echinites of that beautiful species popularly called "*Fairies' night-caps*" (*Cidaris*, *Lign.* 117, *fig.* 3), which are often surrounded by their spines in as perfect a state as if they had just sunk down into soft sand or mud; detached spines of these animals are found (*Lign.* 117, *fig.* 5) in immense numbers.†

Many species of the bivalves called *Trigoniæ*,‡ of which only three species, inhabitants of the Australian seas, are known living, occur in these beds in great perfection and abundance; two species are here figured (*Lign.* 117); limestone-casts of these shells are very frequent in the Portland stone, and are generally accompanied with a *Cerithium*.

13. Oxford Clay.—The Coral-rag rests upon a bed of clay, in many places 300 feet thick, which is characterized

* Most of the heights around Farringdon are capped with shelly sand and sponge-gravel, referable to the Lower Greensand, overlying Coral-rag. Stanford pit, three miles south-east of Farringdon, contains:—1. Uppermost, Coral-rag, 3½ feet; 2. Limestone, with immense numbers of shells, 4½ feet; 3. Sand, 3 feet; 4. Clay. These beds abound in trigoniæ, gervilliæ, terebratulæ, ostræа, belemnites, and ammonites; in a slab of coarse sandy limestone, four feet square, I counted above fifty gervilliæ and many trigoniæ. Between Watchfield and Shrivenham the Coral-rag is seen in openings on the road-side. See Medals of Creation, vol. ii. p. 861.

† See Medals of Creation, vol. i. p. 311, for a particular account of these fossils.

‡ Ibid. p. 412.

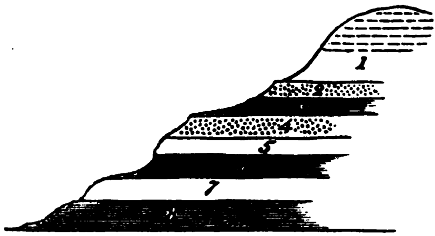
by the abundance and variety of its organic remains. Some localities in Wiltshire are celebrated for the state of perfection in which many species of extinct Cephalopoda occur. At Christian Malford, near Chippenham, the cuttings for the Great Western Railway brought to light specimens of the soft parts of the animals allied to the Sepiadæ or Cuttle-fish, whose shells are so abundant in the argillaceous deposits of the Oolite. The *Belemnoteuthis* (of Channing Pearce),* an extinct cephalopodous mollusc allied to the Belemnite,† but generically distinct, has been found with its arms entire, and the acetabula or suckers and spines attached. In the works for a branch-railway through Trowbridge, the Kelloways rock, Oxford clay, Cornbrash, and Bradford clay were largely exposed, and yielded innumerable specimens of the usual fossils, and some species of ammonites and other shells not previously observed.‡ The members of the upper part of the oolitic system occur

* See London Palæontological Journal, No. 2, Pl. XV. XVI., for beautiful figures of some remarkable specimens of these extinct Cephalopoda. Medals, vol. ii. p. 447, and p. 460. Phil. Trans. 1850, p. 393.

† For a systematic account of the Belemnites and other members of the Cephalopodous family, see Woodward's "Manual of the Mollusca."

‡ Mr. Reginald Neville Mantell made a large collection of the fossils brought to light by the cuttings and excavations in this locality. It comprised very large and fine specimens of Ammonites; Nautili; Belemnites with the phragmocone and traces of the soft parts; the cartilaginous base of the *Belemnoteuthis;* innumerable small gasteropodous shells; Ostrææ deltoideæ; Gryphææ, Terebratulæ, &c.; masses of coniferous wood and lignite; bones of Ichthyosauri, Plesiosauri, Teleosauri, &c.; and a few relics of fishes. The profusion of fossil shells dug up in the comparatively small area traversed by the railway, some of which were inhabitants of deep and others of shallow water, here and there intermingled with drift-wood, attests the effects of sub-marine currents by which the remains of molluscs of such different habitats were accumulated and spread over this area of the sea-bottom, with the spoils of the land transported from a distance by rivers. Quart. Journ. Geol. Soc. vol. vi. p. 315.

through this part of Wiltshire in their natural order of succession; as is shown in the following section (*Lign.* 118), in which the subdivisions of the Chalk and Oolite, from the Upper or flinty Chalk down to the Oxford Clay, are seen in a nearly horizontal and conformable position.



LIGN. 118.—DIAGRAM-SECTION THROUGH THE WILTSHIRE CHALK-DOWNS TO THE OXFORD CLAY.

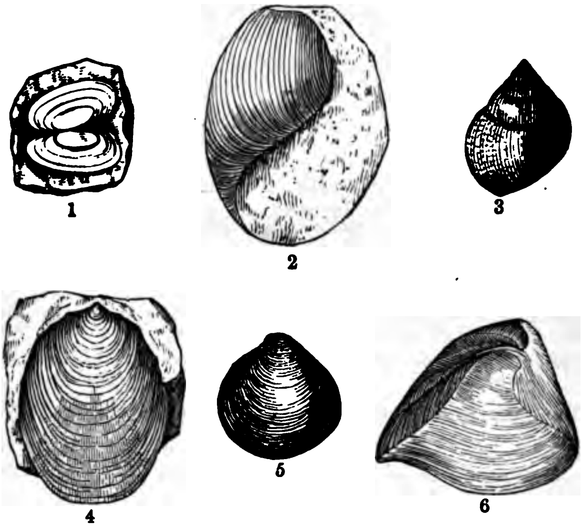
1. Upper and Lower White Chalk. 2. Upper Greensand. 3. Gault. 4. Lower Greensand 5. Portland Oolite. 6. Kimmeridge Clay. 7. Coral-rag. 8. Oxford Clay.

14. KELLOWAYS ROCK AND CORNBRASH. — A bed of gritty and sandy limestone, a few feet in thickness, and sometimes ferruginous, is intercalated with the lower portion of the Oxford Clay in the South of England and in Yorkshire, and is remarkable for the abundance of molluscan remains which it contains. It is called the Kelloways rock; hence a common species of ammonite in this deposit is named *A. Calloviensis.*

Cornbrash.—Under the Oxford Clay a hard rubbly limestone, from ten to twelve feet thick, sometimes passing into clay and sandstone, is generally met with, which, like the Kelloways rock, swarms with many species and genera of marine shells, associated with other fossils. This bed is provincially termed Cornbrash. Subjoined are figures of a few Cornbrash shells from the neighbourhood of Scarborough in Yorkshire, which were first described by Mr. Bean.*

* See *Mag. Nat. Hist.* 1839, vol. iii. p. 57.

In the South-west of England, the Cornbrash, which is persistent as a peculiar shelly deposit from the South to the North of England, is succeeded downwards by, 1st, the



LIGN. 119.—SHELLS FROM THE YORKSHIRE CORNBRASH.

Fig. 1. Sanguinolaria parvula.
2. Bulla undulata. (Occurs also in the Great Oolite of Minchinhampton.)
3. Natica punctura. (Occurs also in the Great Oolite and Inferior Oolite of Yorkshire.)
4. Anomia semistriata.
5. Cardium globosum.
6. Isocardia triangularis.

Hinton Sands and Forest Marble, together about 100 feet in thickness; 2nd, by the Bradford Clay, about 50 feet thick; 3rd, the Great or Bath Oolite, varying from 40 to 120 feet in thickness; 4th, the Fuller's Earth, a series of marly and calcareous beds, of very variable thickness, sometimes 130 feet thick; and lastly by the Inferior Oolite, a group of calcareous and sandy beds, often ferruginous, and sometimes upwards of 200 feet thick. The Inferior Oolite extends into the Midland counties and Yorkshire, although very reduced in thickness; but the other members of the Lower Oolite beneath the Cornbrash are variously represented in the Midland and North-eastern districts, and in the North British area represented by the Oolites of Skye and Brora. Instead of marine calcareous deposits being the predominant feature, sandy and clayey deposits form the mass of the beds; and land-animals, such as insects, the Megalosaurus, and a few mammals, are found in them, whilst remains of land-plants occur occasionally in great profusion. In these circumstances we have indications that the Lower Oolitic rocks of Southern England were formed in a comparatively deep sea (though not of so uniform a depth as that of the preceding Middle and Upper Oolite periods), and that the coast-line of the then existing land lay probably at no great distance to the north-west of our Midland Oolitic area.*

The *Forest Marble* and *Bradford Clay*.—The fissile sandy oolitic beds, or tilestones, of the Forest Marble, have afforded remarkably fine specimens of ripple-markings and tracks of shell-fish and crustaceans; and have evidently originated as local shallow-water deposits, full of broken shells. The more compact shell-beds form the blue limestones, or forest marble of Wiltshire. A series of clay-beds and thin limestones succeed, but are sometimes merged into the Forest

* The student is referred to Mr. Morris's lucid comparison of the Oolitic rocks of Gloucestershire, Lincolnshire, and Yorkshire, in the Quart. Geol. Journ. vol. ix. p. 317, for detailed descriptions and much valuable information on this subject.

The admirable memoir by Mr. Lonsdale on the Geology of the country around Bath should be consulted by those desirous of more ample information on the Oolite of that part of England; Geol. Trans. 2nd ser. vol. iii. p. 242,—and Professor Phillips's Geology of Yorkshire, for a full account of the Oolite system of the eastern moorlands of that County.

Marble above, or the Fuller's Earth beds below. These clays are remarkable in the neighbourhood of Bradford, in Wilts, for the remains of a particular species of crinoid, called the *Pear-encrinite* of Bradford * (*Apiocrinus: Medals*, p. 288), which in some places occur under circumstances apparently indicating that the animals still occupy the spots where they grew. The clay is spread over the surface of a stratum of limestone, and many of the stems of these Stone-lilies are upright, with their root-like bases attached to the calcareous rock; and numerous articulations, once composing the stems, arms, and body of the animals, are scattered at random through the clay.†

15. THE COTTESWOLD HILLS.—As the elevated tract of country called the Cotteswold Hills, which extends for thirty miles through the county of Gloucester, in a N.E. and S.W. direction, having an average breadth of ten or twelve miles, exhibits the principal characters of the jurassic series of the South-west of England, the following brief description of this interesting and typical tract will be highly useful to the student.‡

The surface of this district has a general inclination to the S.E., its eastern borders having an elevation of about 400 to 500 feet above the sea; whilst the western ranges from 600 to 800 feet, and the culminating point, Cleeve Cloud, is 1134 feet high.

The branch of the Great Western Railway from Swindon to Glouces-

* Pictorial Atlas, pl. 1. † Manual of Geology, 5th Edit. p. 307.

‡ This account of the physical geography and structure of the Cotteswolds was communicated to the author by Professor Woodward, formerly of the Agricultural College, Cirencester, now of the British Museum. The student should also avail himself of Mr. Hull's paper on the Cotteswolds, in the Geol. Soc. Journ. vol. xi. p. 477; and his "Memoir on the Geology of the country around Cheltenham," in the Memoirs of the Geological Survey, 1857, illustrative of the Sheet 44 of the Geological Survey Map.

ter passes through the centre of the district, and affords a key to its geological structure.

These hills are entirely composed of two series of oolitic limestones, separated by a bed of clay known to geologists as the "Fuller's Earth." The strata are inclined to the S.E., at the rate of about 1 in 130, or less than half a degree; yet this inclination is greater than that of the general surface, and sufficient to carry the hill-strata beneath the newer formations on the S.E.,; whilst on the north-western boundary they terminate in steep escarpments, that are broken and indented by numerous deep and picturesque valleys.

In order to obtain a general idea of the nature and succession of the strata of the whole district, we may conveniently pursue the well-known Roman road termed the "*Irmin Way*," which, coming from Newbury through the Wanborough downs, runs almost in a straight line to Cricklade, Cirencester, Birdlip, and Gloucester, and traverses in succession the whole of the oolitic strata, in the following order:—

1. Portland stone. 2. Kimmeridge clay. 3. Coral-rag. 4. Oxford clay and Kelloways rock. 5. Great Oolite: subdivided into Cornbrash, Forest marble, Bradford clay, Bath freestone, Stonesfield slate. 6. Fuller's earth. 7. Inferior Oolite. 8. Lias.

1. The *Portland stone* is extensively quarried near Swindon Old Town: 2. The *Kimmeridge clay* forms the valley in which the Swindon station and the New Town are situated: 3. The *Coral-rag* rises up from beneath the clay, and constitutes the hills about Stratton, Saint Margaret's, Pen Hill, and Blunsdon: 4. The *Oxford clay* occupies the whole of Braydon Forest, and the wide valley around Cricklade, but is covered in many places by thick beds of oolitic gravel.

5. At Driffield Cross-ways the *Cornbrash* is seen in the small quarries from which the road-stone is procured; and in descending the hill towards Cirencester we pass to the *Forest marble*, a thin-bedded stone, well shown in the quarries at Preston, from which much of the roofing-stone and planking, so extensively used in the neighbourhood, is obtained. A bed of clay is usually found separating the Forest marble from the Bath freestone, and is therefore the equivalent of the *Bradford clay* Beyond Stratton the road lies over the Bath freestone (or "*Hampton stone*") as far as Highgate, where several deep valleys expose the *Stonesfield slate, Fuller's earth*, and *Inferior Oolite*.

The quarries near Birdlip also exhibit the Inferior Oolite, and the remainder of the road to Gloucester rests upon the *Lias*.

If an Artesian well were sunk at Swindon New Town, it would probably pass through the above-mentioned strata, from the Kimmeridge clay to the Lias, in the same order in which they are passed over by the Irmin Way, reaching the surface of the Lias at a depth of about 1000 feet.

16. THE GREAT OOLITE AND STONESFIELD SLATE.—The Great Oolite of the Western Counties is a calcareous series, in which the well-known Bath Oolite is imbedded. As we trace this series towards the north-east, it becomes much modified, and the lower beds appear to pass into the celebrated Stonesfield Slate * (or tile-stone).

Stonesfield, a small village near Woodstock, about twelve miles north-west of Oxford, has long been celebrated for the fossils imbedded in its thin-bedded limestone; † bones and teeth of large reptiles and of fishes, and other remains from this locality, were described and figured by Lhwyd, more than a century ago.‡

Dr. Buckland's memoir on the great fossil reptile of Stonesfield, the Megalosaurus,§ where he at the same time mentioned the discovery of mammalian jaws in the same deposits, drew special attention to this interesting locality.

The Stonesfield strata have been ascertained, by Mr. Lonsdale, to belong to the lower division of the Great Oolite; from Dr. Fitton's description ‖ of the circumstances under which they occur, we learn that in crossing the country from Oxford to Stonesfield, the Oxford clay with its characteristic fossils is first observed; this is succeeded by the Cornbrash—the uppermost stratum of the Great Oolite group, which is seen beneath the clay in several quarries on the sides of the road to Woodstock and Blenheim. . . . . The village of Stonesfield is situated on the brow of a valley, both sides of which are deeply excavated by the shafts

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* Phillips's Manual of Geology, p. 303.

† Commonly called *Stonesfield slate*. As the term "slate" is technically applied to the old metamorphic *clay-slates* only, it is misapplied to the laminated rock of Stonesfield, which is fissile by its stratification, not by "cleavage."

‡ Lithophylacii Britannici Ichnographia.

§ Geological Transactions, second series, vol. i. p. 390.

‖ Zoological Journal, vol. iii. p. 416.

and galleries that have been constructed for the extraction of the "slate." The beds that supply the stone are at a depth of about fifty feet below the summit, and are worked by shafts. The upper twenty-five feet consist of clays alternating with calcareous stone; the lower of fine-grained oolitic limestone, with numerous casts of shells. From the bottom of the shaft, drifts or horizontal excavations are made around, extending as far as safety will permit; the beds above being supported by piles of the less valuable materials. The strata thus worked do not exceed six feet in thickness; they consist of sandy beds imbedding large calcareous concretions, which, by exposure to the frost, admit of separation into thin flakes.

Fissile calcareous concretions, similar to those of Stonesfield, occur also at Wittering and Collyweston, associated with sandy beds and oolite limestones, and contain ferns and other terrestrial plants, together with marine shells.

17. Organic Remains of the Stonesfield Slate.—The majority of the fossils of Stonesfield, although of so highly interesting a character, have hitherto been very imperfectly investigated. The vegetable remains consist of fucoidal plants, and of palms, arborescent ferns, and plants allied to the Zamia and Cycas, with seed-vessels, leaves, and stems of coniferæ, and traces of reed-like plants. The shells are jurassic in their character; and one small bivalve (*Trigonia impressa*) is extremely abundant. The bones and teeth of the gigantic terrestrial reptile related to the Monitor, the *Megalosaurus*, mentioned above as occurring in the Wealden (vol. i. p. 435), bones of Pterodactyles or flying lizards, bones and plates of Turtles, and other osseous remains, apparently of saurians, present a striking general correspondence with the fossils of the Wealden. The *elytra* or wing-cases of beetles, and other relics of insects, are of frequent occurrence. The teeth, scales, fin-bones, and rays of fishes belong for the most part to the same genera and species as those contained in other jurassic strata; teeth of *Lepidotus* and *Hybodus* are frequently met with;* but

* *See Buckland's Bridgwater* Treatise for figures of several fossils *from Stonesfield.*

by far the most interesting fossils are the mammalian remains.

18. FOSSIL MAMMALIA OF STONESFIELD.*—The laminated oolitic limestones of Stonesfield have yielded some of the most precious relics of the past ages of our globe—most

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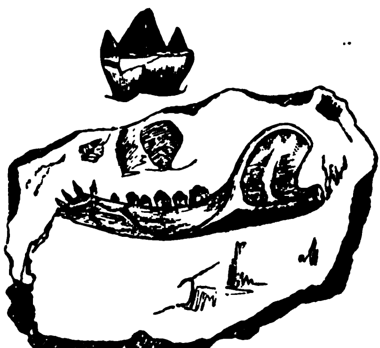

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LIGN. 120.—THE RIGHT SIDE OF THE LOWER JAW OF A MARSUPIAL MAMMALIAN; STONESFIELD

(From Zoolog. Journ. vol. iii. pl. xi.)

Fig. 1. Natural size. Fig. 2. Enlarged view of a single tooth.

(Phascolotherium Bucklandi.)†

of the known vestiges of mammalian animals ‡ in the secondary formations, in other words, in deposits of an age

* See Prof. Owen's Memoir in the Geol. Trans. 2 ser. vol. ii. p. 147; Medals of Creation, vol. ii. p. 805; Petrifactions, p. 401.

† The original is in the British Museum; it is in an admirable state of preservation; and the piece of rock in which it is imbedded has numerous casts of the *Trigonia impressa*, which occur in such profusion in the Stonesfield tilestone.

‡ Emmons's *Dromatherium*, from the Chatham Coal-field of North *rolina*, and *Plieninger's Microlestes*, from the Wirtemberg Bone-bed, *Mammalia* of still more ancient date.

long antecedent to the mammaliferous eocene epoch:—a fact of the highest interest to the geologist, since it carries back the existence of the higher vertebrated animals to a period of unfathomable antiquity.

The mammalian remains hitherto discovered comprise, firstly, a portion of lower jaw, with teeth, of a small pachydermatous animal (the *Stereognathus*),* nearly related to some of the Eocene mammals, such as the *Hyracotherium* and *Pliolophus*; † and, secondly, at least seven specimens of portions of lower jaws, with teeth, belonging to very small animals, and referable to two genera. One of these is allied to the Wombat (*Phascolomys*), a marsupial animal of New South Wales; proving that the remarkable character of the mammalian fauna of Australia also prevailed in a very remote period, and that it is not, as some have inferred, a new order of things. The other was a small insectivorous mammal (*Amphitherium*), having thirty-two teeth in the lower jaw; its marsupial affinities are doubtful.‡

19. COMPARISON OF THE STONESFIELD AND WEALDEN FOSSILS.—We have seen that the zoological characters of the Oolite and Lias are decidedly marine, with intercalations of materials brought down by rivers into the sea, and transported by currents to a more or less distant part of the oceanic basin. Unlike the organic remains of the Wealden, the terrestrial and fresh-water productions are mingled with marine plants, shells, and fishes. Thus, while the Chalk consists of the bed of a deep sea with scarcely any intermixture either of land or fresh-water debris, and the Wealden of a delta in which but few marine exuviæ are imbedded, the Lower Oolitic series presents an intermediate character, of which the Stonesfield strata afford a highly interesting ex-

* Quart. Journ. Geol. Soc. vol. xiii. p. 1.

† Described by Prof. Owen in Geol. Proceed. for May 20, 1857.

‡ In *Prof. Owen's "British Fossil* Mammals," are exquisite figures *and an elaborate philosophical* notice of the mammalian remains discovered in the "Stonesfield slate." See also Lyell's Manual, p. 312.

ample. The reader cannot fail to mark the general correspondence that exists between the organic remains imbedded in these fluvio-marine deposits of the Oolite and those of the Wealden: * the following tabular view will render this analogy more obvious—

Wealden and Purbeck Strata.	*Stonesfield and Collyweston Slates.*
Drifted coniferous wood and lignite.	Drifted coniferous wood.
Equiseta.	Fucoidal plants.
Ferns: Sphenopteris, Lonchopteris, &c.	Ferns: Sphenopteris, Tæniopteris, &c.
Cycadaceæ.	Cycadaceæ.
Carpolithes, and undetermined seed-vessels.	Carpolithes, and undetermined seed-vessels.
Fresh-water shells: Paludina, Cyclas, Unio, &c.	Marine shells — Pteroceras, Trigonia, &c.
Freshwater Crustaceans: Cypridæ.	Marine Crustaceans: Astacidæ, &c.
Insects: numerous genera.	Insects: several genera.
Fishes of the genera Hybodus, Lepidotus, &c.	Fishes of the genera Hybodus, Lepidotus, Strophodus, &c.
Marine and Fresh-water Chelonians.	Marine Chelonians.
Reptiles: *marine* — Plesiosaurus and Cetiosaurus.	Plesiosaurus and Cetiosaurus.
——: *terrestrial* — Megalosaurus, Hylæosaurus, Iguanodon, &c.	Megalosaurus.
Crocodilian—Goniophilis, Pœcilopleuron, &c.	Teleosaurus.
Pterodactyles.	Pterodactyles.
Birds?	Birds?
MAMMALIA: several genera (Purbeck).	MAMMALIA: three genera.

From this table we perceive at a glance, that the fauna and flora of the dry land during the deposition of the Stonesfield oolite and the Wealden-strata were essentially the same; while the difference in the mollusca points out *the respective* conditions under which the deposits took

* *See also Fossils* of the South Downs, &c. 1822, p. 37 and 59.

place: and the same may be said more or less exactly on comparison of the estuarine jurassic beds of Skye and Brora, and of Yorkshire, with the Wealden series. The fresh-water shells of the Wealden indicate the bed either of a delta or a great lagoon; the marine shells of the Stonesfield strata, the basin of a deep sea. Nor can we resist the conviction that not only did the same terrestrial area, however modified it must have been during the long succession of ages, supply the debris of an almost unchanged system of animal and vegetable life to the jurassic seas at first, and subsequently to the cretaceous ocean, but that also the fauna and flora of this ancient land of the secondary epoch had many important features which now characterize Australasia. The Stonesfield marsupials and the Purbeck *Plagiaulax* are allied to genera now restricted to New South Wales and Van Diemen's Land; and it is a most interesting fact, as Professor Phillips was the first to remark, that the organic remains with which these relics are associated also correspond with the existing forms of the Australian continent and neighbouring seas; for it is in those distant latitudes that the waters are inhabited by Cestracions, Trigoniæ, and Terebratulæ; and that the dry land is clothed with Araucariæ, Tree-ferns, and Cycadeous plants.

20. Lithographic stone of Germany.—The quarries in Germany which yield the fine-grained fissile calcareous stone so much employed in lithography, and belonging to the upper portion of the jurassic series, afford also a rich assemblage of organic remains, of the highest interest. This deposit is found in that prolongation of the chain of the Jura which, after the fall of the Rhine at Schaffhausen, passes into Germany along the borders of the Maine and near to Cobourg. The quarries are situated on the sides of the valley of the Altmuhl, a tributary of the Danube, that extends by Pappenheim and Aichsted. This valley presents a precipitous escarpment, which is composed of, 1. (the upper-

most part), fissile calcareous rock, containing in abundance fishes, crustaceans, echinoderms, and reptiles, with a few small ammonites and bivalve shells ;—2. a magnesian limestone ;—

LIGN. 121.—FOSSIL PRAWN, FROM PAPPENHEIM.

(Æger spinipes.)

3. limestone of a greyish-white colour, abounding in ammonites ; and 4. brown or grey sandstone, of a fine grain, constituting the base of the hills of the district.* The most celebrated quarry of the laminated limestone is that of Solenhofen, near Pappenheim. The cream-coloured limestone of this quarry has long been known to contain organic remains of great beauty and interest. Crustaceans allied to the Lobster, Shrimp, &c. are often met with, and many specimens are figured by authors. Knorr's "*Monumens des Catastrophes que le Globe terrestre a essuie*" contains numerous coloured representations of these fossils. The Prawn-like crustacean here figured (*Lign.* 121) shows the extraordinary state of preservation of these remains. Cro-

* *For the* relative age of these Jurassic rocks of Bavaria, see Fraas's *Memoir, Geol. Soc.* Journ. vol. vii. part 2, p. 74.

codilian, Pterodactylian, Chelonian, and other reptiles, upwards of sixty species of fish, forty-six of crustaceans, and twenty-six of insects, have been collected in the Solenhofen beds by Count Münster.* There are but few shells and plants, and these are marine.

Sir H. De la Beche has remarked, that the fact of the greatest number of fossil Insects yet noticed in the Oolite having been found where the remains of the Pterodactyles principally occur seems to establish a connexion between these creatures, not merely accidental; and that it is probable the whole of the deposits of this local group of the Jura-limestone (and those also of Stonesfield) may have been effected on a coast where the water was not deep, and on the shores of which the flying reptiles chased their insect-prey.† The association of insectivorous mammals and reptiles with innumerable relics of insects in the Purbeck beds of Dorset is of equal interest.‡

21. COAL-BEARING STRATA OF THE OOLITE.—We noticed the occurrence in the tertiary system of Provence of beds of coal with limestone containing fresh-water shells and crustaceans (vol. i. p. 264); and in the lacustrine deposits of the Rhine, accumulations of brown-coal and lignite (p. 283). In the Wealden of the South-east of England, lignite and thin seams of coal are associated with shale and laminated sandstones, so much resembling the ancient carboniferous beds as to have led to an expensive and abortive search for coal; while in the north of Germany the Wealden contains a rich coal-field of considerable extent. The fluvio-marine strata of Stonesfield, though teeming with vestiges

* See Münster's Beiträge zur Geognosie und Petrefactenkunde, for descriptions and figures of numerous fossils from the Solenhofen deposits.

† A beautiful fossil Dragon-fly from Solenhofen is figured in Medals of Creation, vol. ii. p. 551.

‡ See Prof. Owen's remarks, Journ. Geol. Soc. vol. x. p. 432.

of land-plants, enclose no considerable masses of vegetable matter; but in the extension of these lower beds of the Oolite northward, indications of lignite and carbonized plants become more abundant; and along some parts of the Yorkshire coast seams of coal and numerous fossil vegetables occur; proving that the currents of fresh water which flowed into that part of the jurassic sea were occasionally loaded with trees and terrestrial plants, transported from the lands inhabited by the Megalosaur, Pterodactyles, and small Mammalians, the remains of which are found at Stonesfield. On the eastern and the western shores of Scotland, strata of a similar character are exposed.

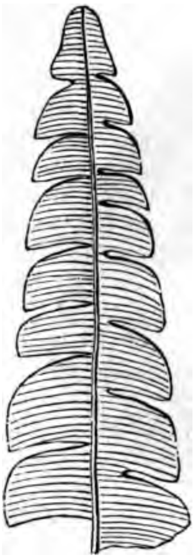
Professor Phillips has described the coal-bearing beds of the Yorkshire Oolite,* and Sir R. Murchison those of Sutherlandshire; † the tabular arrangement at p. 491 shows the succession of the deposits in these two localities.

In Yorkshire the lower Oolite is represented by, 1. a thin Cornbrash limestone; 2. a thick mass of sandstones and shales abounding in coaly matter; and 3. ferruginous sandy beds, overlying the Lias. The carbonaceous matter takes the form of seams of coal, which, though thin, are, from local circumstances, of considerable value. These strata assume the appearance of a true coal-field, with subordinate beds of coarse shelly limestone. Indeed, Prof. Phillips has remarked that in the Lower Oolitic series of Yorkshire there are five plant-bearing bands of sandstone and shales (occasionally yielding coal in three zones), four calcareous bands, and several layers of ironstone. Here, observes Professor Phillips, we have truly a coal-field of the Oolitic era, produced by the intercalation of vast quantities of sedimentary detritus loaded with vegetable matter, brought down by floods

* Encyclopædia Metropolitana, art. *Geology;* Manual of Geology; and the Geology of Yorkshire, by the same eminent philosopher. See also Geol. Proceed. for June, 1857.

† Geol. Transact. 2nd series, vol. ii. p. 293 and 353.

from the land, between the more exclusively marine strata of the ordinary Oolitic type. The fossil plants which accompany the coaly sandstones occur also in the calcareous beds, both on the Yorkshire coast and at Brandsby. No marine exuviæ have yet been found in the coal-grits or shales. Along the coast under Gristhorp cliffs, a seam of shale, but a few inches in thickness, may be traced for miles; and, from its abounding in leaves of ferns and equisetaceous and cycadaceous plants, it is chiselled out by collectors to obtain specimens; for the beauty and variety of these fossils render them objects of great interest. Detached leaves (*Lign.* 122) in a carbonized state are very abundant, and their venation is generally well preserved. Professor Phillips has figured several kinds in his "Geology of Yorkshire:" and numerous species are described in Lindley and Hutton's "British Fossil Flora." * The fruits of Zamia-like plants also occur, and many splendid examples are preserved in the British Museum † and other collections. This specimen (*Lign.* 123) shows the usual appearance of these fossil fruits; it is imbedded in dark ironstone-shale, and the leaves and their imprints are covered with a white hydrate of alumina. Some of the fossils that have been described as flowers are conjectured to be bodies of this kind, broken transversely, in which state the



LIGN. 122.—PART OF A LEAF OF PTEROPHYLLUM COMPTUM; from near Scarborough.

* See also Quart. Geol. Journ. vol. vii. p. 179; and Medals of Creation, vol. i. p. 152.

† *Petrifactions*, p. 55.

scales may be mistaken for petals, and the fractured axis for the stamen and pistillum.

LIGN. 123.—FRUIT OF A CYCADACEOUS PLANT FROM SCARBOROUGH.

The seeds are concealed by the leaflets.

(Zamites lanceolatus.)

22. COLLYWESTON TILESTONES.—Near Stamford, in Lincolnshire, the lowermost visible strata are Lias-clays, upon which are spread the ferruginous beds of the Inferior Oolite; and above are beds of laminated calcareous stone, locally termed the "Collyweston slates," from being quarried in that neighbourhood.* These deposits, therefore, appear to

* *See* Quart. Journ. Geol. Soc. vol. ix. p. 335.

occupy the same geological position as the Stonesfield tile-stone of Oxfordshire and of the Cotteswold hills, and contain similar marine shells. They are associated with marly limestone. The fossils are shells of the genera *Pterocerus*, *Nerinæa*, *Lucina*, *Modiola*, *Trigonia*, &c., with numerous fragments of the leaves of ferns (especially of *Pecopteris polypodioides*), and of cycadaceous plants. These beds have been regarded by Captain Ibbetson and Mr. Morris as the equivalents of the carbonaceous shales of Scarborough and Gristhorp Bay; in fact, as the seaward extension of those fluvio-marine strata. Those of Stonesfield appear to have been synchronous, but deposited still farther from land.

23. Coal-bearing Oolite of Brora.—Carbonaceous fluvio-marine deposits of a similar character to, and of the same Lower Oolite age as, those above described occur in the north of Scotland.* At Brora, on the south-east coast of Sutherlandshire, intercalated between the Middle or Oxfordian Oolites and the Lias, there is a series of deposits consisting of, 1st, shelly limestones, representing the Cornbrash and Forest-marble; 2. sandstones, shale, and ironstone, with remains of land-plants; 3. shelly limestone with fossil wood; 4. sandstone and shale with plant-remains, and containing towards the top two beds of coal. In the neighbourhood of Elgin also, and on the north-east coast of the Isle of Skye, shales and sandstones with impressions and remains of similar plants are met with, superimposed on the Lias.†

The fossil plants are for the most part of the same type as those of Yorkshire, and are associated with fresh-water or brackish water shells of the genera *Cyclas* or *Cyrena*, *Unio*, and *Paludina*. *Tellina* and *Perna* have also been found; and

* For a general view of the geological phenomena of Scotland, the reader is referred to the instructive little volume by Prof. James Nicol, entitled, A Guide to the Geology of Scotland, 1844.

† Sir R. Murchison, Geol. Trans. 2 ser. vol. ii. p. 293; Mr. Robertson, Geol. *Proceed. vol. iv. p. 173*, and Geol. Journ. vol. iii. p. 113; and *Prof. E. Forbes, Geol. Journ.* vii. p. 107.

Cypridæ (p. 419) occur in profusion. Scales and teeth of numerous small ganoid fishes, of genera common in the Oolite (*Hybodus*, *Lepidotus*, and *Acrodus*), abound in some of the layers of clay: fragments of plates and bones of Chelonians are among the few reptilian relics hitherto observed.

These coal-bearing deposits have evidently had the same origin as those of north-eastern Yorkshire, where Uniones and Cypridæ are associated with Ferns, Zamiæ, Thuyites, and other terrestrial plants. Taken as a whole, the fluvio-marine intercalations of the Oolite must be regarded as local accumulations of the spoils of the land, transported into the sea by the agency of rivers; the presence of coal depending on the streams being largely charged with vegetable remains; or perhaps, in some cases, to the subsidence and covering up of swamps and lagoons rich with vegetable growths. They belong to a period long antecedent to the deposition of the Wealden, which was subsequent to the formation of the upper Oolites.

24. Jurassic Coal-field of Eastern Virginia.—One of the most remarkable features in the geology of the United States of North America, as contrasted with that of Europe, consists in the absence of deposits yielding jurassic fossils such as, throughout large tracts in England and Europe, represent the vast interval of time that must have elapsed between the close of the Triassic and the commencement of the Cretaceous epoch. Some time since, it was suggested by Professor W. B. Rogers, that an extensive coal-field in Eastern Virginia* belonged to the Jurassic period; and Sir C. Lyell coincides in this opinion. This coal-field is about twenty miles from north to south, and from four to twelve miles in breadth from east to west. It is situated in a

* There are two coal-fields in the State of Virginia; the remarks in the text exclusively refer to the Eastern coal-field,—that near Richmond; the coal-measures in Western Virginia belong to the ancient Carboniferous system.

granitic region, and the lowermost bed of coal rests upon granite. Quartzose grits, sandstones, and shales are intercalated with the coal, as in the carboniferous system of Europe. Beds of rich bituminous coal, one being in some places from thirty to forty feet thick, occur in the lower division.*

The fossil plants resemble those of the Oolite of Yorkshire (*Pecopteris Whitbiensis*, *Equisetum columnare*, some species of *Zamites*, *Tæniopteris*, *Neuropteris*, &c.), differing specifically, and most of them generically, from those of the older coal-formations. From the upright position of many of the Equiseta, Sir C. Lyell infers that the vegetables which produced the coal grew on the spot where they are now found, and that the strata were formed during alternate subsidences and elevations of this part of Virginia. They contain fossil fishes (*Tetragonolepis* and *Catopterus*†) related to European Liassic species; and numerous *Cypridæ* and *Estheriæ*, the latter of which, under the name of *Posidonomyæ*, are characteristic of some strata of the European Trias. Prof. Rogers finds reasons to regard this coal-field of Eastern Virginia as belonging to the same series of deposits as the red sandstones and coaly shales of Carolina to the South, and of Maryland, New Jersey, and Connecticut, to the North. These beds are characterized by the local occurrence of *Estheriæ* and *Cypridæ*, reptilian bones, and plant-remains; and in Connecticut, by numerous impressions of supposed birds' tracks. They have been variously referred to the Trias and the Permian series; but probably more or less fully represent in time, as extensive land and

* Plant-beds and coal of similar characters as the above have been found near the Rocky Mountains, at Raton Mountain and Muddy River.

† Sir P. Egerton's genus *Dictyopyge* consists of some of Mr. W. C. Redfield's *Catopteri*. See Silliman's Journal, 1856, vol. xxii. p. 357, and *Geol. Soc. Journal*, vol. iii. p. 275.

fresh-water formations, the Upper Trias and Lower Jurassic periods.*

In India and South Africa, and probably in Australia, similarly characterized deposits, possessing both Triassic and Jurassic elements, are recognized.†

In the Chatham coal-field (North Carolina), of this age, Dr. Emmons ‡ has discovered some lower jaws of a small species of mammal, which he has named *Dromatherium sylvestre*. They much resemble some of the little marsupial jaws from Stonesfield and Purbeck. Dr. Emmons has also figured and described § a fossil sacrum of a bird from the same series of deposits,—referred by him to the Permian age.

25. The Lias.—The lowermost group of the Oolitic or Jurassic system, termed the Lias, consists of stratified blue and grey marls, clays, and limestones, amounting in total thickness to from five hundred to one thousand feet, and abounding in many peculiar fossils. The principal lithological features are the uniform aspect and distinctly stratified character of the limestones and intervening argillaceous layers; the most constant subdivisions are those mentioned in the table, ‖ p. 490.

* The Wealden may in like manner be said to be the equivalent of the Upper Jurassic and Lower Cretaceous series.

† See Mr. T. R. Jones's remarks on this subject in the Geol. Soc. Journ., vol. xii. p. 376.

‡ American Geology, part vi. p. 93, 1857.

§ Ibid. p. 148.

‖ In 1856 Dr. T. Wright, of Cheltenham, published in the Quarterly Journal of the Geological Society a paper, to show that the sands usually referred to the Inferior Oolite in the West of England contain fossils of the Liassic type, and should be classified as with Lias, and not with the Lower Oolite. Although Mr. Hull, of the Geological Survey, has accepted Dr. Wright's views, and carried them out in his description of the geology of the country around Cheltenham (Memoirs Geol. Survey, 1856), yet there are too many dissentients to these views amongst experienced geologists, and too many openings for criticism in

It may be stated in general terms, that the Lias of England extends along the western escarpment of the Oolite, from Yorkshire to the Dorsetshire coast, forming a district which presents an exceedingly variable surface, occasioned by the disruption and subsequent denudations which the strata have undergone.

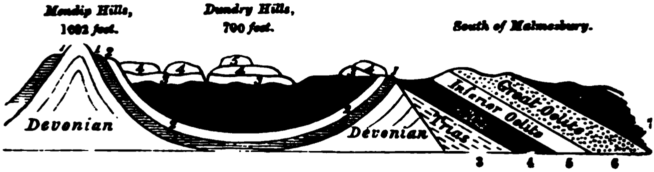
The Lias,* from its northernmost limits on the Yorkshire coast, where it underlies the strata of the Eastern Moorlands,† passes to the south of Whitby and to the east of York, and crosses the Humber near the junction of the Trent and Ouse; stretching onward beneath the low Oolitic range of Lincolnshire, it extends to the Wold hills, on the borders of Nottingham and Lincoln, to Barrow-upon-Soar; whence it continues, accompanying the escarpment of the Inferior and Great Oolite, through Nottingham, Warwick, and Gloucester. Its whole course, to within a few miles south of Gloucester, is remarkably regular, presenting an average breadth of about six miles, bounded on the south-west by the Oolite, and on the north-west by the Red Marl, which will hereafter be described. Beyond Gloucester, its range becomes intricate; its eastern limit accompanies the Oolite through Somersetshire to Lyme Regis; but the western is very irregular, feathering in and out among the coal-fields which occur towards the estuary of the Severn and the upper part of the Bristol Channel, Gloucestershire, Somersetshire, Monmouthshire, and Glamorganshire, and attended with numerous outlying or detached masses. To render the course and position of the Lias in this part of England intelligible, it is necessary to state, that this dis-

Dr. Wright's arguments, to allow of our altering the present classification of these beds, which, though possibly passage-beds, and partaking of the characters of the two series, have too much in common with the Oolite to be separated from it.

* Outlines of the Geology of England and Wales, p. 261.

† In the Lias of the Eske Valley there are two great beds of ironstone, which are *extensively* worked.

trict is occupied by three great basins of the coal-formation, encircled by the underlying Mountain-limestone and De-



LIGN. 121.—SECTION FROM SOUTH OF MALMESBURY THROUGH THE MENDIP HILLS.

1. Mountain-limestone, overlying Devonian rocks. 2. Millstone-grit, underlying the coal-beds. 3. Triassic and Permian strata. 4. Lias. 5. Inferior Oolite. 6. Great Oolite. 7. Oxford clay.

*(From the Geology of England and Wales.)**

vonian sandstones; one of these basins is shown in the annexed section.

The edges of these basins consist of strata thrown up at a high angle, and often nearly vertical, forming bold and precipitous ranges of hills; in the valleys, horizontal layers of Lias, with subjacent beds of red-marl (*Lign.* 124), are seen lying unconformably upon the highly inclined coal-measures. I shall recur to this subject hereafter, and now only observe, that the Lias appears beneath the Oolite through the south-east of Somersetshire, and passes into Dorsetshire, where the overlying Greensand conceals it beneath the high range of the Black Down Hills.

At Lyme Regis it forms a range of cliffs, about four miles in length, and may be traced until it gradually sinks beneath the Inferior Oolite of Bridport. The skeletons of large marine reptiles (*Ichthyosauri* and *Plesiosauri*), for which the Lias is celebrated, have principally been found in the cliffs at Lyme, Watchett, Westbury, and Whitby, where the natural sections, formed by the action of the waves, well

* The inclination of the strata is very much exaggerated in this diagram, in consequence of the difference in the horizontal and vertical scales, necessarily adopted to comprise the section in a small space.

display the characters of the strata, and afford abundance of fossil remains. The Lias appears in the Western Isles of Scotland, and on the north-east coast of Ireland. The Upper Lias comprises a thin band of limestone, rich with remains of insects and fish, which has been traced from Somersetshire and Gloucestershire into Northamptonshire and Lincolnshire.*

In the north and south-east of France, and over a large area in Germany, the Lias, with its peculiar fossils, accompanies the Oolite. One species of Gryphite (*Gryphæa incurva, Lign.* 117, *fig.* 6), which is so abundant in the Liassic strata of England, on the Continent forms a limestone (*Calcaire à gryphites*), which, like the Sussex-marble and many other such rocks, is composed of shells cemented together by a calcareous paste. In Wirtemberg the Lias presents the usual characters of that of England, and contains remains of Ichthyosaurs and other reptiles.†

In the valley of the Arve, in Switzerland, the Lias-clays are of great thickness, and, owing to the ancient effects of igneous or metamorphic agency everywhere apparent in the Alps, have a schistose character, strongly assimilating them to the primary slates.

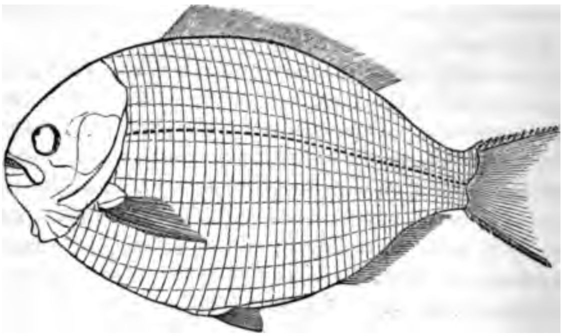
In Russia oolitic deposits cover detached districts, from the Icy Sea to the Caucasus in the south; and in Russia Proper there are shales and sands referable to the Middle or Oxford Oolite; a characteristic species of ammonite (*A. biplex*) of the Portland-rock has been found both in Russia and Poland. In the Himalayas and Central India argillaceous beds occur which contain fossils, which have been regarded as analogous to those of the Lias of Europe.

Bone-bed.—At the base of the Lias, and separating the

* By Messrs. C. Moore, Binfield, Morris, and Brodie: Medals, vol. ii. p. 549. Annals N. H. 2 ser. vol. xix. p. 56.

† See Dr. Jaeger's work, *Ueber die fossilen Reptilien, welche in Würtemberg aufgefunden worden sind.* Stuttgard, 1828.

lower shales and limestones from the uppermost Triassic bed beneath, there is a layer of coarse detritus, a few inches thick, commonly known as the *Lias Bone-bed*,* from the



LIGN. 125.—RESTORED FIGURE OF THE DAPEDIUS OF THE LIAS.

(One-sixth the natural size By M. Agassiz.)

immense quantities of water-worn bones, teeth, and coprolites of fishes, which it contains. It is, in fact, an aggregation of mud, sand, and the debris of fishes and reptiles. Teeth of fishes of the genus *Ceratodus* (Med. Creat. p. 587), are very frequent in this bed. Aust Cliff, on the Severn, near Westbury, in Somersetshire, is a well-known locality for the fossils of this remarkable deposit. By some geologists this bone-bed is included in the Trias, and by others in the Lias. A similar stratum occupies the same geological position in Germany, and contains organic remains of a like nature.

* Another "bone-bed" occurs in the Upper Ludlow series (Geol. Journ. vol. xi. p. 8); and fish-remains are almost as abundant in a portion of the Mountain-limestone (at Clifton and Armagh), and in the *Inferior Oolite* at Leckhampton Hill. (See Quart. Geol. Journ. vol. vii. 211.)

Considerable interest is attached to the exact determination of the extent of this "bone-bed," and its associated strata, from England to the Eastern Alps. In the west it appears to have been a comparatively shallow-water deposit; but towards the east it is imbedded in other fossiliferous strata that were evidently deposited in a deeper sea. These shelly beds form part of the series termed "Koessen-strata" by the Austrian geologists, and without doubt belong to the Upper Trias. A bone-bed, similar to that underlying the English Lias, occurs near Stuttgard,* and certain sandstone strata there accompanying it are, according to Messrs. Oppel and Suess, the littoral equivalents of the marine "Koessen-strata," so well developed in the Eastern Alps, and characterized to the eastward of Vienna, in the Austrian Salinar district, and even partly in the Alps of Tyrol and Bavaria, by numerous remains of marine animals, especially of Brachiopods and Oysters. In the Vorarlberg, these forms begin to disappear, giving place to Pecten Valoniensis, Cardium Rhæticum, Card. Austriacum, and other pectinibranchiates, indicative of a diminution of the depth of the old sea there. Beyond the overlying strata of more recent date, and along the shores of that primæval sea, these deposits have assumed quite a littoral character; Oysters and Brachiopods having totally disappeared, and the pectinibranchiate molluscs, such as occur in these beds in the Vorarlberg, and some new species, being predominant in the fossil fauna. Hence it is concluded that the "Koessen-beds" are contemporaneous with the ossiferous strata or bone-beds, the existence of which may be traced for a great distance, from the South-west of Germany to France and England.

* The Stuttgard "bone-bed" is famous for having yielded some minute teeth of a Mammalian animal (Lyell's Manual of Geology, 1855, p. 343, and Supplement, 1857). This will be noticed in the chapter on the Trias, the *Stuttgard deposits* having been referred to that formation.

26. ORGANIC REMAINS OF THE JURASSIC SYSTEM.—The fossils discovered in the Oolitic and Liassic strata amount to many hundred species,* and it is impossible in a work of this nature to give but the briefest summary of these organic remains; it must suffice to offer a few general remarks on the nature of the fauna and flora of the sea and land during the vast period of time which the accumulation of sediments of such extent and thickness must have required.

Vegetable remains.—Some species of fucoidal plants and upwards of a hundred species of terrestrial vegetables have been determined from the Jurassic rocks of Britain. The latter consist of ferns, cycadaceous plants, and coniferous trees; constituting a flora analogous to that which now prevails in the maritime districts of the West Indies, New Holland, and the Cape of Good Hope, &c. A large species of plant allied to the recent Marestail (*Equisetites columnaris*) is abundant in the coal-bearing Oolite; and in Yorkshire so many of these plants occur in an erect position that it is supposed they must have grown on the spots they now occupy: we shall recur to this fact hereafter.

One of the most remarkable fossil vegetables discovered in this formation in England is the fruit of a tree (*Podocarya Bucklandi*, Unger) allied to the Pandanus or Screw-pine, from the lower Oolite of Charmouth in Dorsetshire.†

Fragments of trunks of coniferous trees of the Araucarian type are found throughout the Jurassic formation; and, as we have already stated, the last bed of the Oolite, when

* The student is referred to Prof. Phillips' tables of fossils in the Encyclopædia Metrop., art. *Geology*, to Sir H. De la Beche's Manual of Geology, and to Mr. Morris's British Fossils, for lists of the fossils found in the British Oolite and Lias; and to the beautiful work on the organic remains of the "*Terrains Jurassiques*," by M. D'Orbigny. See also Medals of Creation.

† Dr. Buckland's Bridgwater Treatise, vol. ii. pl. 63.

elevated above the waters, was clothed with pine-forests (vol. i. 400).

The quantity of drift-wood in a carbonized state, but not converted into coal, is very considerable in the argillaceous strata. In the Oxford-clay, at Trowbridge,* masses of wood occur in abundance; oysters, terebratulæ, and other shells are often adherent to the fragments of trunks and branches of trees, which have evidently been drifted from a distance into the bed of the sea. Much of this wood is soft and flexible when first exposed, and, when dry, burns with a bright flame. In the Lias of Whitby, Lyme Regis, and other localities, the wood is often calcareous, and admits of a fine polish: occasionally silicified masses are met with.†

27. Zoophyta and Radiaria.—Of corals and moss-corals numerous jurassic species abound. The reefs of coral constituting the Coral-rag have already been alluded to. In some parts of Germany coralline Oolites are largely developed, and all the corals are silicified in certain localities; this is especially the case between Nattheim and Heidenheim,‡ whence exquisite specimens of *Astræa*, *Lithodendron*, &c. have been obtained.

In the beds of chert in the Oolite of Tisbury in Wilts, shells and corals are found in a beautifully silicified state, particularly a species of *Isastræa* (*I. Tisburiensis*). Large silicified masses of this coral are met with, which, on being cut and polished, display the intimate structure of the original, and form an ornamental material for the jewellers and lapidaries. A matchless specimen of the soft parts of a *Trigonia*, transmuted into silex, was obtained from Tisbury by the late Miss E. Benett, and is now, with the greater

* See above, p. 500.

† Beautiful specimens of the fossil wood and plants from the Lias and Oolite are exhibited in the British Museum. *Petrifact.* Chap. I.

‡ Geol. Soc. Journ. vol. vii. part 2, p. 71.

part of the collection of that lady, in the possession of Mr. Wilson of Philadelphia.*

The Crinoidea, or lily-shaped animals, are also abundant, and are often found in an admirable state of perfection. Whole slabs of many of the Lias-shales are covered with Pentacrinites, frosted with brilliant pyrites, and lying in relief on the stone, as if spread out on the sea-sand.†

Of the *Echinoidea* upwards of seventy species, and of Star-fishes nearly twenty genera, comprising many species, have been determined from the British Oolites.‡ Some splendid Star-fishes from the Yorkshire Oolite and Lias are figured in Charlesworth's London Geological Journal, pl. 17 (*Astropecten arenicola*), and pl. 19, 20 (*Ophiodermata*).

LIGN. 126.—AMMONITES COMMUNIS; *from the Lias of Whitby.*

28. MOLLUSCA.—The shells, both of testaceous and conchiferous molluscs, amount to many hundred species. Of the *Cephalopoda*, as Nautili, Ammonites, Belemnites, &c., several hundred species, belonging to numerous genera, have been figured and described.§

The state of perfection in which the animals allied to the Cuttle-fish occur in the Lias, and also in the clays of the

* Figures and a description of this extraordinary British fossil have been given by Mr. Charlesworth in the London Geological Journal.

† See Petrifactions, &c., p. 88.

‡ Dr. Wright's Monograph, published by the Palæontographical Society, 1856, furnishes a careful and lucid history of the Jurassic Echinoderms of Britain.

§ See Sowerby's Mineral Conchology, and the works before referred *to.*

Oolite, especially in the Oxford-clay of Wiltshire,* is most extraordinary. The soft part of the body and arms, the capsule of the globe of the eye, and the ink-bag still retaining its inspissated secretion, are often found in their natural position, and distinctly recognisable. This state indicates a rapid imbedding of the animals while in their natural element.†

29. Crustaceans and Insects.—Numerous genera of Crustaceans and Insects have been collected from the Jurassic deposits: the museum of the late Count Münster was celebrated throughout Europe for the magnificent series of remains of this kind which it contained.

Species allied to the Shrimps, Prawns, Lobsters, and Crabs have been found in great perfection at Solenhofen, Pappenheim, &c.; an extinct form (*Eryon Cuvieri*‡), and some *Limuli*,§ occur in an exceedingly perfect state; and small bivalved Entomostraca are not rare in some beds, though as yet they are undescribed.

A fine fossil Dragon-fly, from Solenhofen, in the cabinet of the Marquess of Northampton, is figured in Medals of Creation (vol. ii. p. 551). In England, the Coal-measures, Lias, Stonesfield-slate, Forest-marble, and Wealden have yielded fossil insects. Among the specimens found in the Lias, is a wing of a very large Dragon-fly, which closely resembles the recent species in the general arrangement of the nervures, and appears not to be separable from the genus *Æshna* (*Lign.* 127). In this fossil an opaque spot (*a*) exists on the anterior margin of the wing, as in most of the living Libellulidæ.

Mr. Brodie has figured and described numerous fossil insects from the Oolite and Lias of England,‖ comprising

* See the London Geological and Palæontological Journal, No. 2, Pl. XV. XVI., for figures of some remarkable specimens in the late Mr. Channing Pearce's cabinet.

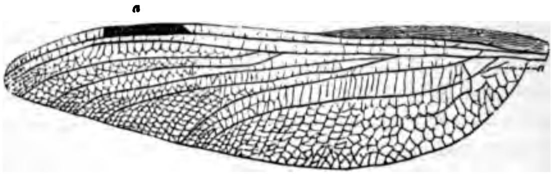
† See Dr. Buckland's Bridgwater Treatise, for exquisite figures of the shells and soft parts of Cephalopoda.

‡ Medals, ii. p. 520.

§ Ibid. p. 522.

‖ History of Fossil Insects (1845), p. xiv. In this work will be found

Coleoptera, Neuroptera, Hemiptera, and Homoptera. The wings of insects allied to the recent genus *Panorpa* have been found in the Lias of Wainlode Cliff, on the banks of the Severn.*



LIGN. 127.—FOSSIL WING OF A SPECIES OF DRAGON-FLY; FROM THE LIAS OF BIDFORD, WARWICKSHIRE. (*Nat. size.*)

a, Spot on the margin of the wing.

(*Æshna Liassina, of Mr. Strickland* †)

The several hundred specimens of fossil insects that have been discovered in the Lias belong nearly all to forms that inhabit temperate climates, and present a remarkable affinity to existing families; so that in one instance only has Mr. Westwood, the distinguished entomologist, ventured to propose a new generic nam ‡ The same fact of the close relationship of the fossil to the recent types of Insecta holds good, with but one or two exceptions, in the case of the insects from the Purbeck beds.

30. FISHES.—All the Fishes of the Oolite are referable to extinct genera, and essentially differ, as a whole, from those

an account of the localities in which insect-remains had been at that time discovered in the secondary rocks of England. See also Dr. Buckland's Bridg. Treatise; and Medals of Creation, vol. ii. p. 547, &c.

* See Medals of Creation, vol. ii. p. 553.

† Mag. Nat. Hist. vol. iv. p. 301. See Nova Acta Car. Leop. Acad. vol. xix. part 1, for Germar's fossil Insects from Solenhofen.

‡ Mr. Strickland, on the results of recent researches into the fossil insects of the secondary formations of Britain: Brit. Assoc. Reports for 1845, p. 58.

of the cretaceous epoch. Teeth, scales, dorsal spines, and other remains of *Hybodus*, *Acrodus*, *Asteracanthus*, *Ganodus*, *Eugnathus*, *Pachycormus*, *Pycnodus*, *Æchmodus*, *Lepidotus*, and *Pholidophorus* are abundant in some of the strata.*

Among the Ichthyolites that prevail in the Lias, the scales and teeth of a genus of Ganoids called *Dapedius* are especially abundant, and entire specimens of the fish are often met with. I am led to notice this genus more particularly, that your attention may be directed to a remarkable modification of structure observable in the Ichthyolites of the more ancient deposits, which will hereafter come under our examination. The Dapedius belongs to that division of the *Lepidoids* which are *homocercal* (equal-tailed) or nearly so;† while all the genera from the palæozoic strata are *heterocercal*, or having tails with unequal lobes.‡ But few of the existing genera of fishes have this latter condition of the caudal fin, while it is found in almost every fossil species below the Triassic deposits.§

31. Reptiles of the Jurassic system.—The prevalence of animals of the reptilian class during the Oolitic era was incidentally alluded to in the course of our previous observations on the organic contents of the different members of this extensive formation. From the lowermost stratum, the Bone-bed of the Lias, to the uppermost layer of the Portland-stone, the remains of extinct reptiles have

* See Medals of Creation, vol. ii. chap. xiv. xv.; and Petrifactions and their Teachings, chap. v.

† It is difficult to determine whether some of the Triassic and Liassic Lepidoid fishes are really homocercal or not. Quart. Journ. Geol. Soc. vol. x. p. 368.

‡ See Medals of Creation, p. 575; Petrifactions, p. 421.

§ It is worthy of remark, that in the embryotic state most fishes are heterocercal; and those species which, when arrived at maturity, have the equally-lobed tail attain this homocercal type in the progress of their development. For remarks on the heterocercality of the Salmonidæ, &c., see Mr. Huxley's observations in the "Notices of the Royal Instit." 1855, p. 84.

been found more or less abundantly in every deposit. About forty species, belonging to several genera, have been determined as occurring in the Jurassic strata of the British Islands. These have been carefully investigated and described by Professor Owen, in the Reports of the British Association for 1840 and 1841, and in the Monographs on Fossil British Reptiles published by the Palæontographical Society. Cuvier, Gervais, Hermann von Meyer, Jaeger, Burmeister, and Theodori are amongst the continental naturalists who have studied the fossil reptiles.* As I shall have occasion to recur to this subject in the sequel, it will be sufficient in this place briefly to enumerate the principal kinds hitherto discovered in the Oolite and Lias.

In addition to the reptiles of which remains have been found in the Chalk and Wealden, namely, the Megalosaurus (p. 435), Pœcilopleuron (p. 432), Cetiosaurus (p. 427), Streptospondylus, Pterodactylus, Ichthyosaurus, Plesiosaurus,—and of some of these, especially of the two last-named genera, numerous species abound in the Lias and Oolite,—several other Crocodilian reptiles, with peculiar osteological modifications, also occur. These are the Teleosaurus, Steneosaurus,† &c., which are characterized by their long narrow muzzles, sharp-pointed teeth, short fore-legs, imbricated scales, and doubly concave or flat-faced vertebræ: their relics are chiefly found in the Lower Oolite and Lias.

The most remarkable circumstance relating to the Ichthyosauri and Plesiosauri that swarm in the Lias is the connected state in which all the bones of the skeleton occur. The entire osseous frame-work, from the extremity of the snout to the last vertebra of the tail, often remains entire,

* See Pictet's *Paléontologie*, 2nd Edit. vol. ii., for a *résumé* of our knowledge of fossil reptiles.

† See Medals of Creation, vol. ii. p. 679. These gavial-like reptiles are represented amongst the other extinct animals by life-like models in the Crystal Palace Gardens.

or but very little displaced from its natural position; even the bones of the paddles, with their cartilaginous appendages, are in some instances preserved.* The indigestible portion of the food of these carnivorous marine reptiles (as the scales, teeth, and bones of fishes), and their coprolites, are frequently met with in the abdominal cavity.† These facts show that the carcasses of these animals were imbedded in the soft mud at the bottom of the sea, without having been exposed to the action of the billows, or to long transport by rivers or currents. The Wealden fossils present a striking contrast in this respect; for, although bones of Plesiosauri are by no means uncommon in that formation, they are isolated and generally water-worn.

In the Kimmeridge Clay, the relics of a very large marine saurian, allied to the Plesiosaurs, but distinguished by certain osteological characters, have been met with: this extinct reptile is named Pliosaurus. Bones of Flying-Saurians, or Pterodactyles, occur more abundantly in the Oolite and Lias than in any other series of deposits; more than twelve species have been found in the Solenhofen and other Bavarian quarries. In the Stonesfield-slate the bones of one species (*Pterodactylus Bucklandi*), and in the Lias of Lyme Regis, a considerable part of the skeleton of another (*P. macronyx*), have been discovered. The Mammalia of Stonesfield have already been noticed (p. 508).

The general character of the Jurassic or Oolitic formation, as derived from its organic remains, is therefore that of a series of oceanic deposits, accumulated in a depression of great extent, through a period of immense duration. The sea teemed with marine invertebrate animals, belonging to genera and species most of which became extinct before the

* See Medals of Creation, vol. ii. p. 669.

† Consult Dr. Buckland's Bridgwater Treatise, p. 198; and Geol. Trans. 2 ser. vol. iii. p. 223.

Tertiary epoch; and with these were associated multitudes of peculiar Fishes and Reptiles. The dry land, as attested by the remains drifted into the basin of the sea, was inhabited by a few reptiles and marsupial mammals, and was clothed with tree-ferns, cycadeous plants, and coniferous trees; and insects, pterodactyles, and possibly birds,* flew above its surface.

* The Rev. Mr. Dennis's microscopical evidences (Microscop. Journ. vol. v. p. 63) only require further patient investigations to substantiate the fact of the existence of Birds' remains in the Stonesfield slate. The same observant naturalist has brought forward very probable evidences of the mammalian character of some bones from the "Lias Bone-bed" of Lyme Regis (*ibid.* vol. iv. p. 261).

LECTURE V.

PART II.—THE TRIAS AND PERMIAN FORMATIONS.

The Trias and Permian Formations. 2. Geographical Distribution of the Trias and Permian. 3. Rock-Salt and Brine-Springs. 4. Origin of Rock-Salt and Gypsum. 5. The Cheltenham Waters. 6. Conglomerates of the Trias. 7. Organic remains of the Trias. 8. Crustacea, Mollusca, and Crinoidea. 9. Fishes of the Trias. 10. Reptiles of the Trias. 11. The Labyrinthodon. 12. The Rhynchosaurus. 13. The Dicynodon of Africa. 14. Foot-prints on stone. 15. Ornithichnites. 16. Triassic Mammal. 17. The Permian System. 18. Magnesian limestone or Zechstein. 19. Permian of Germany and Russia. 20. Organic Remains of the Permian System. 21. Invertebrata of the Permian. 22. Fishes of the Permian. 23. Reptiles of the Permian. 24. Reptiles. 25. Chelonians or Turtles. 26. Crocodiles. 27. Enalio-saurians or Marine Reptiles. 28. The Plesiosaurus. 29. Pterodactyles, or Flying Reptiles. 30. Ophidians and Batrachians. 31. Review of the Age of Reptiles. 32. Objections considered. 33. Concluding Remarks.

1. The Trias and Permian Formations.—Beneath the Lias there is a series of strata, many hundred yards in total thickness, which was formerly known in geology as the *New Red Sandstone Formation*, and divided into two groups, namely the Upper and the Lower. But later investigations * having shown, that, of the fossils found in the lowermost group, scarcely a species is known in the upper series, nor in any newer strata, this system is now separated, under the name of "Permian," from the former, and regarded as the uppermost or terminal group of the *Palæozoic* or primary series ; while the Upper New Red is ranked as the lowermost of the *Mesozoic* or secondary formations.† The name of *Trias*, or Triassic System, by which the Upper New Red is now distinguished, relates to the well-marked triple sub-

* See Phillips's "Manual of Geology," 1855, p. 246, 247.

† See the "Synoptical Arrangement," p. 203.

division of this series in Germany, and has been adopted to avoid confusion from the restricted application of the old term. The New Red Sandstone series has also been termed the "Pœcilitic" from the variegated colours of its component strata; and "Saliferous," on account of the immense beds of rock-salt which alternate with the red marls in Cheshire and other parts of England. The following table shows the characters and order of succession of the principal Triassic and Permian deposits:—

THE TRIASSIC OR NEW RED FORMATION.

(*Comprising the Keuper, Muschelkalk, and Bunter-Sandstein, of the German geologists.*)

1. Variegated, red, blue, greenish, and white marls or clays (with gypsum and immense beds of rock-salt in some places), interstratified with sandy beds; the sandstones towards the bottom, called "Water-stones," constituting a well-defined band.

[These marls and sandstones attain a thickness of about 1000 feet, and are equivalent to the "Keuper;" the "Muschelkalk" being possibly represented by the "white beds" or "waterstones."]

2. Red and variegated sandstones and marls.
3. Coarse red sandstones and conglomerates.
4. Red and variegated sandstones and marls.*

[Nos. 2, 3, and 4 collectively have a thickness of more than 1000 feet.]

THE PERMIAN OR MAGNESIAN-LIMESTONE FORMATION.

(*Comprising the Bunter-Schiefer, Zechstein, Kupfer-Schiefer, and Roth-todt-liegendes,*† *of the Germans.*)

1. Reddish sandstones, and red and white gypsiferous marls, with thin limestone-beds. (About 200 feet thick).
2. Magnesian limestone (*Zechstein*); white, red, or yellowish magnesian limestone, sometimes concretionary, sometimes brecciated, in thick beds, with marine organic remains. (About 500 feet thick.)

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* See Quart. Journ. Geol. Soc. vol. ix. p. 188, for Prof. Ramsay's account of the four subdivisions of the English "Bunter."

† *Roth-todt-liegendes,* signifying "red dead layer," is a German mining term, denoting that the copper of the upper beds has died out, this layer not being metalliferous.

3. Marl-slate and limestone, in thin layers, containing fishes and sea-shells. (About 60 feet thick.) The *Kupfer-Schiefer*, or Copper-schist, of Mansfeld.
4. Variegated marls, sandstones, and conglomerates (Pontefract Rock) of variable thickness and character.* (About 200 feet thick.)

From this tabular view, the Trias and Permian systems are seen to consist of red and variegated marls, generally gypsiferous, sandstones, magnesian limestones, and conglomerates, more or less coloured with peroxide of iron; the upper group containing beds of salt and gypsum; and the lower, calcareous rocks, having in their composition a large proportion of magnesia. As a whole, the strata are comparatively poor in organic remains; but in some localities land-plants, marine shells, and reptiles are met with; certain species and genera being peculiar to each system. The fossils of the Permian rocks are very closely allied in their zoological characters to those of the coal-formation; the organic remains of the Trias, on the contrary, are very distinct, having closer relations to those of the secondary formations, especially the Lias.

2. Geographical Distribution of the Trias and Permian.—For the sake of conciseness I shall comprise both systems in the following brief notice of their geographical distribution.†

From the River Tees to the Tyne (*see the map*, Pl. I. p. 474), these rocks form the Durham coast. The line of the emergence of the New Red from beneath the Lias through Yorkshire to the south-west forms its eastern boundary. Traversing Yorkshire and Nottinghamshire as an irregular band varying from 10 to 30 miles wide, the New Red is accom-

* The sands and sandstones beneath the marl-slate in Durham are believed by Mr. R. Howse not to belong to the Permian series, on account of their unconformability, and their being characterized by genuine carboniferous species of plants and fish. Annals N. H. 1856.

† *In the map, Plate I. the* Trias and Permian are both *denoted by the same colour and number* (5).

panied by a still narrower band of Permian rocks to the west as far as Nottingham, from whence as far as Warwick and the vale of the Severn * to the south-west, and to Shrewsbury and the Lancashire coast on the west and north-west, the New Red spreads out irregularly, comprising the rich salt-fields of Cheshire and Worcestershire, and surrounding or bordering on the several coal-fields of the Midland counties, Flintshire, and Lancashire, each with its irregular selvedge of Permian strata. In Somerset and Devon the New Red accompanies the Lias. It also forms the vale of the Clwyd in North Wales, and that of the Eden in Cumberland, where it is uniformly bordered with Permian rocks. The latter occur also in an isolated patch in Anglesea,† and are represented in the South-western counties by conglomeratic beds near Bristol, on the sides of the Mendips, and near Exeter.

The New Red of Cumberland is continuous with the sandstone area of South-eastern Dumfriesshire; but the red sandstones of the upper part of Annandale (Corncockle Muir, Moffat, &c.), and of Dumfries and the vale of the Nith, are referred by Messrs. Binney and Harkness ‡ to the Permian series. In Ireland, Permian fossils have been found at Cultra,§ near Belfast, and at Artrea,‖ and Roan Hill, Tyrone.¶ The great breadth of the district of which the Triassic beds form the subsoil, in their western expansion, arises from the New Red marls and sandstones of the North-western and the Southern counties being nearly horizontal beds, for the most part free from overlying deposits, and succeeding to the disturbed underlying strata, which had previously been thrown up, at various and often considerable angles, into lofty groups and chains of hills, which appear like so many islands amidst the great plain of Redmarl (see section of the Mendips, p. 522).**

On the Continent, the Triassic and Permian groups, with occasional variations in the strata, may be traced nearly opposite the Devonshire coast, skirting the palæozoic rocks of Brittany; and

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* A valuable paper by Murchison and Strickland on the "New Red of Gloucestershire," &c. will be found in Geol. Transact. 2nd series, vol. v. p. 331. See also Murchison's *Siluria*, p. 300, &c.

† Lately noticed by Professor Ramsay, Local Director of the Geological Survey.

‡ Quart. Geol. Journ. vol. xii. p. 138, and p. 254.

§ Journ. Geol. Soc. Dublin, vol. i. p. 175. ‖ *Ibid.* vol. vii. p. 67.

¶ Geol. Proc. vol. ii. p. 206; Portlock's Report, Londonderry, p. 468; and Quart. Geol. Journ. vol. iii. p. 4.

** See also the map of the Mendips in De la Beche's Geological *Observer, p. 478.*

to the South-east, underlying the Jura-limestone, and containing beds of gypsum and salt, they occur in patches on the flanks of the gneissic area of Central France. They have a great extent in Central Germany, stretching from the Hundsrück to the Vosges on the west of the Rhine Valley, and from the Hartz to the Black Forest on its eastern side. They are traceable also as a zone on either side of the Alps. In Saxony, Silesia, and Poland there are isolated tracks of these strata, but they prevail in the north and east of European Russia; the great extension of the Magnesian limestone series over and around the Government of Perm having suggested to Sir R. Murchison the present geological name of this formation. Triassic rocks are known in several parts of Spain and Portugal.*

The Trias of Germany, distinct in its triple character, is well developed in Bavaria and Wirtemberg. Immediately beneath the Lias is the series termed the *Keuper*,† which consists of variegated red and green marls and sandstones, containing intercalations of salt and gypsum, as in England, and some coaly beds. This group is superimposed on a fine cream-coloured "shell-limestone," or *Muschelkalk*, which abounds in organic remains; especially in that beautiful extinct crinoidean, the *Lily encrinite* (*Lign.* 131), which is exclusively found in this bed, and chiefly near Brunswick: the Muschelkalk is not known to occur in England. The lowermost series of the Trias is the *Bunter-Sandstein*,‡ consisting of variegated sandstones and marls, resembling those of the Keuper. The lower portion of the Bunter (Bunter-Schiefer) has been separated from this group to be allocated to the Permian series.§

In the United States of North America red sandstones and shales, usually referred to the Trias, occupy the lower part of the valley of the

* The Geological Map of Europe, by Murchison and Nicol, is a good guide for the student in studying the extension of these and other formations.

† In Western Europe the junction-beds between the Lias and the Keuper appear to be a thicker development of the "Bone-bed," associated with some shelly bands. Towards the East, these are found to be of more and more importance, until, in the Austrian Alps, they thicken out into several distinct beds, locally known as Koessen-beds, Dachstein-beds, Hallstatt-beds, St. Cassian-beds, Guttenstein-beds, and Werfen-beds.

‡ Variegated or spotted sandstone.

§ See Murchison and Morris on the Permian rocks of Thuringia and the Hartz, Quart. Journ. *Geol. Soc.* vol. xi. p. 426.

Connecticut, and are continued into New Jersey, Maryland, Virginia, and North Carolina, and similar strata occur on each margin of the Bay of Fundy and in Prince Edward Island. These red sandstones are associated in some places with coal-bearing shales, sometimes abounding in plant-remains and fishes which comprise forms both of palæozoic and secondary types. The Connecticut sandstones are invested with an extraordinary degree of interest, from the abundance and variety of the foot-prints of unknown animals with which the surface of some of the laminated sandstones are impressed; a phenomenon we shall presently examine.

Some traces of Permian rocks have been detected in Spitzbergen, and Muschelkalk-fossils have been detected by Capt. R. Strachey in the Himalayas.*

8. Rock-salt and Brine-springs of the Trias.—In England and Ireland (Carrickfergus),† the Trias is the chief repository of salt or chloride of sodium: and brine-springs, which are subterranean streams of water impregnated with salt from percolating through saliferous strata, are abundant in the great plain of the red marls and sandstones of Cheshire. The salt, however, is not uniform in extent, but occupies limited areas.

The saliferous strata of Northwich present the following series:—

	Feet.
1. Uppermost calcareous marl . . .	15
2. Red and blue clays	120
3. Bed of rock-salt	75
4. Clay, with veins of rock-salt . .	31
5. Second bed of rock-salt	110

Droitwich, in Worcestershire, which is situated nearly in the centre of the county, has been celebrated for the production of salt from its brine-springs, from the time of the Romans; and this inexhaustible fountain of saline water has continued ever since flowing up, and yielding salt in

* Quart. Geol. Journ. vol. vii. p. 305.

† Two beds of rock-salt, underlying upwards of 630 feet of red gypsiferous marl, and making together a thickness of more than 120 feet, were discovered at Carrickfergus by the enterprise of the Marquis of *Downshire.* (*Jukes*, Geology, p. 245.)

undiminished quantities.* It is probable that the manufacture is coeval with the town itself; but it was not until the year 1725, that the strong brine for which it is now famous was discovered; from one spring alone, the enormous quantity of a thousand tons of salt have been obtained per week.†

At a distance of from thirty or forty feet below the surface there is a bed of hard gypsum, about 150 feet thick; through this a small hole is bored to the river of brine, which is in depth about twenty-two inches, and beneath which is rock-salt. The brine rises rapidly through the aperture, and is pumped into a capacious reservoir, whence it is conveyed into iron-boilers for evaporation: it is supposed to be stronger than any other in the kingdom, and contains above one-fourth part its weight of salt. One of the shafts is sunk to a depth of nearly 500 feet, and passes through four layers of salt, 85 feet in aggregate thickness. Some of the beds of salt in Cheshire are from 70 to 120 feet thick. A red sandstone, containing vegetable remains, forms the foundation-rock of the saliferous deposits of England.‡

4. ORIGIN OF ROCK-SALT.—The origin of these enormous subterranean beds of rock-salt is as enigmatical as that of the saltness of the waters of the ocean. But deposits of salt, though prevailing in England and the Continent in the formation under examination, are not confined to any particular group of strata. The celebrated salt-mines of Galicia (see p. 289), and numerous salt-works in Persia and Western Asia, are made in tertiary strata; § while in the State of New York salt and gypsum, with variegated marls, are

* The Romans imposed a tax on the Britons who worked the Droitwich salt-mines, and made salt a part of the pay of their soldiers' *salarium*, or salary. Hence the custom of asking for salt at the Eton Montem.—*Geology of England and Wales*, p. 282.

† From Mr. R. Hunt's Report in the Mining Records we learn that the quantity of white salt manufactured from brine in the districts of Wansford and Northwich (Cheshire) in 1855 was 834,514 tons; at Droitwich and Stoke (Worcestershire), 170,000 tons.

‡ For an interesting account of the salt-works at Droitwich, see Mr. Hugh Miller's "Impressions of England and its People," p. 179.

§ According to Dr. A. Fleming, the saliferous beds of the Salt-Range in the Punjaub are of the Devonian age.

found in the Silurian system.* It is to be remarked, that deposits of chloride of sodium are almost always accompanied with layers and intercalations of gypsum; and the circumstance of two powerful acids, the sulphuric (in the gypsum or sulphate of lime), and the hydrochloric (in the chloride of sodium), being so largely and uniformly present, seems to indicate a common origin; both occur abundantly as volcanic products. In a more advanced state of chemical science, this fact may probably tend to the elucidation of the question under consideration.†

The gypsum associated with rock-salt is considered by several eminent observers to be anhydrous, that is, entirely free from water, before exposed to moisture. The great beds of gypsum that occur with rock-salt at Bex, in Switzerland, were found by M. Charpentier to be anhydrous when laid open to the atmosphere. Hence Mr. Bakewell suggests that the consolidation of the salt and gypsum must have been effected in such cases by heat, for there is no conceivable mode of aqueous deposition that could form

* In the middle of the horizontal Silurian rocks of the State of New York, there is a formation of red, green, and bluish-grey marls, with beds of gypsum and occasional salt-springs, the whole being from 800 to 1000 feet thick, and undistinguishable in mineral character from parts of the Trias of Europe.—*Lyell's Travels in America*, p. 54. See also J. Hall's "Geology of New York," 4to, 1843, for notices of the salines and gypsum in the Medina and the Onondaga rocks.

† In treating of the gypsiferous rocks that overlie the nummulitic series in Turkey and Persia, Mr. W. K. Loftus has suggested that volcanic action, suddenly altering the level of the sea-bed and discharging sulphuric vapours into the sea, might have caused the deposition of the gypseous beds, by the chemical change of the calcareous matter held in solution in the water; and that the usual absence of animal remains in such deposits might be similarly accounted for. Mr. Loftus also refers to volcanic agency as the probable cause both of the formation of the rock-salt of the Plain of Khoi (about 80 miles south of Ararat), and of the *excessive saltness of* the Lake Urumia. Quart. Geol. Journ. vol. xi. *p. 268, 307, and 309.*

anhydrous gypsum.* The red colour of the salt and marls is occasioned by oxide of iron, which may have been derived from decomposed volcanic rocks.

That many of the deposits of salt may have originated simply from the evaporation of sea-water pent up in lagoons, lakes, or inland seas, is a generally received and not improbable supposition; but the absence of marine organisms of any kind has been regarded as a formidable objection to this hypothesis.† Another difficulty presents itself in the enormous thickness of many of the beds of salt; which, if considered as the solid residuum of sea-water, must have required a body of fluid inconceivably great; unless we suppose the seas of those ancient periods to have contained a much larger proportion of saline ingredients than the present,—an inference for which there are no reasonable grounds whatever. If we imagine successive subsidences of a given area to have taken place, the alternations of beds of marls with layers of salt of variable thickness may be explained; but the difficulties above mentioned remain in full force. As gypsum ‡ and the chlorides of sodium are often sublimed from volcanic vents, an igneous origin has been ascribed to many of the beds of salt and sulphate of lime. Gypsum is unquestionably, in many instances, a metamorphosed substance; for sulphurous fumes, acting on beds of clay containing shells, convert the lime into selenite; and, acting on limestone, convert it into fibrous and compact gypsum. Many tertiary gypseous deposits have evidently originated from this cause: but crystals of gypsum are also abundantly found in

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* Mr. Bakewell's "Introduction to Geology" (5th edit. p. 289) contains an interesting review of this problem, and an account of the most important deposits of salt.

† It cannot, however, be with certainty determined, whether the absence or paucity of fossils in a deposit is owing to an actual reduction of the amount of life in the seas of a given area, or to the mineral character of the strata not having been favourable to the preservation of organic remains.

‡ Gypsum, or sulphate of lime, consists of sulphuric acid, 46·31; lime, 32·90; and water, 20·79. The massive gypsum is called *Alabaster;* the transparent gypsum, *Selenite;* powdered calcined gypsum forms *Plaster of Paris.* The fibrous gypsum has a silky lustre, and is used for ear-rings, brooches, and other ornaments. Fibrous gypsum of great beauty occurs in Derbyshire: veins and masses of this substance abound in the red marls bordering the valley of the Trent.

beds containing pyrites, from the decomposition of the sulphide of iron, and the formation of sulphate of lime from the action of the liberated sulphuric acid on the calcareous materials.* In many parts of Sicily, vapours charged with sulphuric acid are constantly emanating from vents or fumaroles, as they are termed, and throw down large deposits of sulphur and gypsum ; and the fumes of sulphur and boracic acid escape in such quantities, that the peasants put pots, and often bee-hives, over the fumaroles, and thus collect abundance of sulphur and boracic acid. In Tuscany, boracic acid is obtained from jets of vapour which force their way through secondary rocks in contact with serpentine.†

The connexion between volcanic action and the formation of gypsum seems also pointed out by the fact, that in North America, where volcanic rocks are not associated with the coal-measures, there are no beds of gypsum : but in Nova Scotia, where igneous rocks are interpolated beneath the coal, there are extensive gypseous deposits. Sir C. Lyell, after a careful review of the phenomena exhibited by these gypsiferous strata, expresses his conviction, that the production of gypsum in the Carboniferous sea was intimately connected with volcanic action, whether in the form of stufas or heated vapours, or of hot mineral-springs, or some other effects of sub-marine igneous eruptions.

It may be also remarked, that the variegated appearance of the marls —red, pink, blue, yellow, dun, &c.—of the Trias, seems to have been produced by the chemical effects of vapours or fluids charged with sulphuric or chloric acid; at least the same change is induced on the tertiary marls of the Lipari Isles by the gaseous emanations and vapours of the fumarôles and hot springs.

5. THE CHELTENHAM WATERS.—In certain localities where the marls of the Trias are covered by other beds, and the saline springs force their way to the surface through the superincumbent deposits, chemical changes take place in these solutions of chloride of sodium, which thus acquire

* See Mr. Morris's paper in Mag. Nat. Hist. 1838, p. 43. Recent railway-embankments of shelly clays (such as the London, Kimmeridge, and Oxford Clays) often exhibit this phenomenon, and are liable to give way from their consolidation being thereby prevented.

† See a highly interesting Memoir on the Geology of some parts of Tuscany, by W. J. Hamilton, Esq., Quart. Geol. Journal, vol. i. p. 274; also Sir R. Murchison's description of the Tuscan fumaroles and soffioni, Quart. Geol. Journ. vol. vii. p. 367.

other properties, and become what are termed mineral-waters; such is the origin of the celebrated Cheltenham waters.*

The town of Cheltenham is built on Lias clays and marls, beneath which, but at a great depth, lie the Triassic deposits, the reservoir of the rock-salt and brine-springs, whence the mineral waters have their origin, and derive their saline ingredients; but these undergo various modifications in their passage to the surface through the superincumbent beds of Lias, which are full of iron-pyrites, and sulphate of lime. "From the analyses of these waters by

LIGN. 128.—DIAGRAM-SECTION OF THE STRATA BENEATH CHELTENHAM.

(From Sir R. I. Murchison's Sil. Syst.)

1, 1, Red marl. 2, 2, 2, Origin of the Cheltenham Waters. 3, 3, Lias clays and marls. 4, Alluvium.

several chemists, it appears that their principal constituents are the chloride of sodium, or sea-salt, and the sulphates of soda and magnesia; sulphate of lime, oxide of iron, and chloride of magnesium being present in some wells only, and in much smaller quantities. . . . . . Besides these ingredients, *iodine* and *bromine* have been detected by Dr. Daubeny, who endeavoured to ascertain whether these two active princi-

* See Sir R. I. Murchison's description of the mineral-springs of Gloucestershire and Worcestershire, "Silurian System," p. 34; and in his "Geology of Cheltenham," 2nd edit. p. 63. The Lias and Trias of this district are described *in full detail* in the *Sil. Syst.* pp. 16, &c.

ples, which the French chemists had recently discovered modern marine productions, did not also exist in mine salt waters issuing from strata which geologists consider have been formed beneath the sea."

As the saline springs of the red marls rise up throu the Lias (*Lign.* 128), they undergo certain chemi changes. From the decomposition of the sulphate of ir which takes place, a vast quantity of sulphuric acid must generated, which, reacting on the different bases of magnes lime, &c., contained in the strata, forms those sulphates prevalent in the higher or pyritous beds of the Lias; t oxide of iron being at the same time more or less complet separated. By this means the mineral-waters, which probably mere brine-springs at the greatest depths, acqu additional medicinal qualities as they ascend to the pla whence they flow. At the same time it must be borne mind that fresh water is continually falling from the atm phere upon the surface of the Lias clays, and percolati through the uppermost strata.

6. Conglomerates of the Trias.—The conglomera of this formation are chiefly composed of pebbles a detritus derived from the destruction of igneous and me morphic rocks, as slate, quartz-rock, granite, porphy &c.; and the fine siliceous sandstones contain a large p portion of such debris. It would, therefore, appear that t sea which deposited the saliferous group was bounded the rocks of whose ruins it is composed; in like manner the existence of beaches of flint-pebbles evinces the destru tion of former chalk-cliffs.

The rock on which Nottingham Castle is built is a co glomerate formed of the ruins of the ancient rocks of t neighbouring districts. The rounded pebbles of quar lydian stone, granite, jasper, porphyry, slate, &c., seem have originated from rocks formerly connected with t range of Charnwood Forest. Still nearer the Charnw hills, the finest sandstone contains fragments of slate. Mr. Bakewell was of opinion that a large proportion of the materials of the Triassic strata was derived from trap and other igneous rocks; and that the red marl was the debris arising from the decomposition of the less indurated volcanic products; hence, probably, the extreme fertility of the soil.*

7. Organic Remains of the Trias. — This formation presents a remarkable contrast with that of the Jurassic, in the paucity of organic remains; for, while the latter teems with marine fossils, the former, throughout immense areas, is almost wholly destitute of any vestiges of animals or vegetables; a proof that the strata were, for the most part, accumulated under conditions unfavourable for the preservation of organic structures. Several Fucoidal plants, between thirty and forty species of Ferns,† nearly twelve of Cycadeæ, and about fourteen referable to Coniferæ, have, however, been obtained and determined. Among these are fronds of a plant bearing some resemblance to the

Lign. 129.—Fossil plant allied to the Adder's-tongue; from the red marl, Sulz-les-Bains.

(*Crematopteris scolopendrioides; one half the natural size.*)

Adder's tongue (*Asplenium scolopendrium*), so common on the banks of our woods and copses; a specimen discovered by M. Voltz exhibits the fructification on the back of the leaf (*Lign.* 129). But the most characteristic plants of

* Introduction to Geology, fifth edition, p. 279.

† Fragments of the large fronds of the *Anomopteris Mougeoti*, from the Bunter, are *figured in the Medals*, vol. i. p. 117, and Petrifactions, p. 32.

the Triassic flora are Coniferæ, belonging to a genus named *Voltzia*,* which differ from any now living, but somewhat resemble the Araucaria, or Norfolk Island pine. Fragments

1 2

LIGN. 130.—CONIFERÆ OF THE TRIAS: FROM SULZ-LES-BAINS.

Fig. 1. Voltzia longifolia.
— 2. —— heterophylla; with the fructification.

of these fossil plants are frequent in the greenish marls near Strasburg: two specimens of portions of branches are figured in *Lign.* 130; *fig.* 2 shows the fructification.† Several

* From the late Mr. Voltz of Strasburg, by whom they were first discovered.

† *See Essai* d'une Flore du Grès Bigarré; par M. Ad. Brongniart, *Ann. Sciences* Nat., 1828.

species of equisetaceous plants (*Calamites* and *Equisetites*) abound; one of which is probably the *E. columnaris* of the Lower Oolite.

A very remarkable fossil (*Dictyophyllum crassinervum* *) has been found in the Triassic sandstone near Liverpool; it is a leaf of considerable size, bearing a striking resemblance to the foliage of some of the thick-ribbed cabbages.† I will only add, that, as a whole, the flora of the Trias, or New Red, presents a general character by which it is separated alike from the vegetation of the older formations below, and of the Lias above, though showing a strong affinity to that of the latter.

8. Crustacea, Mollusca, and Crinoidea.—Crustaceans are rare in the Trias, with the exception of one genus of small bivalved entomostracans, allied to the recent *Estheriæ*, and commonly confounded with the molluscan *Posidonomyæ*. This little *Estheria* (*Posidonomya minuta*) is characteristic of the Keuper deposits of England and the Continent; and similar fossils occur in the red shales of Virginia and Pennsylvania.‡ M. Schimper § has figured and described some Xiphosures or Limulus-like Crustaceans from the Trias of Alsace. Polypiferous zoophytes or corals, which are so abundant in the Jurassic formation, are very rare in the Trias.‖ The shells comprise a few species of Cardium, Trigonia, Mya, Plagiostoma, Ostræa, Pecten, Avicula, Terebratula, and other Bivalves, with several Gasteropoda, some Nautili, and numerous Ammonites and Ceratites.¶ The Radiaria consist

* The "thick-nerved net-leaf."

† Lindley's Foss. Flora, pl. 201, and Murchison's, "Silurian System," p. 43.

‡ See Mr. Jones's Notice of this fossil in the Quart. Geol. Journ., vol. xii. p. 376.

§ Mém. Mus. Hist. Nat. Strasbourg, vol. iv. 1853.

‖ One or two species occur in the Muschelkalk, and two in the Hallstatt-beds, of the Austrian Alps; Denksch. Akad. Wien, vol. ix. p. 167.

¶ Medals, vol. ii p. 483.

of a few Star-fishes, Cidarides, Pentacrinites, and Encrinites. Of the latter, a most beautiful form of this family of Crinoi-

Lign. 131.—The Lily Ecrinite, from the Muschelkalk, near Brunswick.

*(Encrinus liliiformis.)**

deans is exclusively found in the Muschelkalk, namely, the *Lily Encrinite* (*Lign.* 131), so named from the supposed

* First figured and described by Schlotheim; and subsequently, as *E. moniliformis*, by Miller. Baron von Strombeck has written an interesting description, with illustrations, of the deformities of this species in the "Palæontographica," vol. iv. p. 169.

resemblance of the animal, when in repose, to a closed lily: in the lecture on Zoophytes, &c., I shall describe this elegant fossil more particularly: the specimens hitherto obtained are from the neighbourhood of Brunswick.

9. Fishes of the Trias. — The bone-bed that intervenes between the Lias and Trias (see p. 524), contains teeth and dorsal rays of numerous small fishes of the genera *Acrodus*, *Ceratodus*, *Gyrolepis*, *Hybodus*, *Nemacanthus*, and *Saurichthis*; similar remains occur, although but rarely, in the sandstones and conglomerates.* Only one species † of the Palæoniscus, a genus of fishes common in the Permian and Carboniferous formations, has been identified in the Trias.

10. Reptiles of the Trias.—The Triassic strata not only contain teeth and bones of several remarkable reptiles, but also bear the foot-marks, or imprints of the feet, of many animals, both biped and quadruped, of whose existence no other traces have, as yet, been discovered. Although the true geological position of some of the strata bearing such imprints is somewhat doubtful (for some geologists question whether a great part of the so-called New Red of North America may not be referable to the Permian group), whilst others associate it with the Jurassic series, it will be convenient to notice the phenomena in question in this place; I will, therefore, first describe the reptilian remains, and afterwards examine the fossil foot-marks.

Bones of several species of Ichthyosaurian and Plesiosaurian reptiles have been found in the Triassic strata of Wirtemberg by Dr. Jaeger of Stutgard. But the most extraor-

* Fish-teeth and Ichthyodorulites have been found in the conglomerate of the Keuper at Pendock, by the Rev. Mr. Symonds (Quart. Geol. Journ. vol. xi. p. 451); and in the gritty sandstone near Warwick, by the Rev. Mr. Brodie (*Ibid.* vol. xii. p. 374). A very peculiar and homocerque fish (*Dipteronotus cyphus*) has been figured and described by Sir P. Egerton from the Bunter-sandstone of Bromsgrove. (*Quart. Geol. Journ.* vol. x. p. 367).

† *Palæoniscus superstes*, Egerton; Geol. Proceed. June, 1851.

dinary reptilian remains discovered in that country and described by the same eminent physician, H. von Meyer, and Burmeister, belong to enormous Sauro-batrachians, or animals allied both to Crocodilians and the Frog-tribe. The principal fossils consist of portions of the cranium, jaws with numerous teeth, and an occipital bone, with a double articulating surface, — a proof of its batrachian affinity. Teeth, portions of the skull and jaws, and a few other bones, of similar extinct Sauro-batrachian or Labyrinthodont reptiles have also been found in Warwickshire, and have been described by Professor Owen.

11. THE LABYRINTHODON.*—The teeth of the gigantic reptile of Wirtemberg † (some of which are two inches long), and those from Warwickshire,‡ are of a gently curved conical shape, and possess a remarkable complicated character, produced by the convergence of numerous labyrinthine folds of the external layer of cement towards the pulp-cavity; and within these inflections the dentine, or tooth-ivory, is similarly disposed. Transverse sections, therefore, display the most beautiful interfoldings of the two substances; and, as the fossils are generally deeply coloured by iron or manganese, they exhibit, under a slightly magnifying power, an extremely interesting appearance; § this peculiarity of organization suggested the name assigned to this peculiar genus of fossil reptiles.

From the structure of the cranium, it appears that the Labyrinthodon, of which there are six English species, had subterminal nostrils leading to a

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* Medals of Creation, vol. ii. p. 741.

† Dr. Jaeger gave the names of *Salamandroides* and *Mastodontosaurus* to the Labyrinthodont animal of Wirtemberg.

‡ According to Prof. Ramsay (Journ. Geol. Soc. vol. xi. p. 198), some at least of the Labyrinthodont remains found in Warwickshire occur in Permian, and not Triassic strata.

§ *Medals of Creation*, vol. ii. p. 744, Pl. VI. fig. 3. See Prof. Owen's wide and shallow nasal cavity, separated from the cavity of the mouth by a broad and almost continuous horizontal palatal flooring. It is, therefore, inferred that these reptiles breathed air like the crocodiles, and were probably furnished with well-developed ribs: thus these early representatives of the Batrachians belong to a higher condition of structure than any true Batrachia now known to exist.* These gigantic Sauro-batrachians must have borne the same relation in magnitude to the diminutive existing members of the frog-tribe, as the extinct colossal Mosasaur and Iguanodon to the recent Monitors and Iguanas.†

Cladyodon. — Several detached, pointed, trenchant, recurved teeth, the crowns of which are an inch long, and five lines broad at the base, have been found in the Warwickshire sandstone. They closely agree with the teeth of the Thecodont reptiles of the Permian; but Professor Owen regards them as generically distinct, and has named the reptile to which they belonged the *Cladyodon*.‡

12. Rhynchosaurus.—The New Red sandstone quarries at Grinsill, in Warwickshire, have yielded the remains of a very anomalous modification of reptilian organization, combining the lacertian type of skull with edentulous jaws. The general aspect of the cranium resembles that of a bird or turtle; the intermaxillary bones being very long, and curving downward, thus imparting to the fore-part of the head the profile of a parrot. There are no teeth apparent in

descriptions and figures, Geol. Trans. 2 ser. vol. vi.; *Odontography*, p. 195; and *Cyclop. Anat.*, Art. *Teeth.*

* "As in the existing diversified order of Batrachia, one family (*Perennibranchiata*) represents Fishes,—a second (*Ceciliadæ*), Serpents,—a third genus (*Pipa*), Chelonians,—and a fourth (*Salamandra*), Lizards,—so would the now lost Labyrinthodonts have formed Batrachian representatives of the highest order of Reptiles, viz. the Crocodilians."—*Prof. Owen, in Brit. Assoc. Rep.* 1841, p. 197.

† The relative proportions of all these great reptilian monsters can be easily studied in the Crystal Palace Gardens, where Mr. Waterhouse Hawkins has so boldly, truly, and artistically wrought into tangible shape the *ideas of the* comparative anatomist.

‡ *Report on British* Fossils, Rep. for 1841, p. 155.

either jaw, and Professor Owen supposes that this reptile may have had its jaws encased by a bony or horny sheath, as in turtles. Footmarks of a small reptile, with the print of a hind-toe pointed backwards, occur on the surface of some of the slabs of sandstone in these quarries, and are, with much probability, conjectured to have been impressed by the Rhynchosaurus.*

13. DICYNODON.—Although the geological position of the strata whence the specimens were obtained is somewhat uncertain, yet the relation between the reptiles whose remains I am about to describe and that last mentioned induces me to notice them in this place. The fossils in question were collected by Mr. Bain, in hard limestone-nodules occurring in a sandstone, supposed to belong to the Triassic system, in South Africa,† and were sent, with many other specimens of undescribed reptiles, to the Geological Society.‡ The principal remains hitherto cleared from the rock belong to reptiles having a flat cranium, with nostrils divided as in lizards, and not confluent as in turtles, which otherwise the skull in its general appearance much resembles. The orbits are very large; the jaws are edentulous, as in the Rhynchosaurus above described, with the exception that the upper jaw possesses a pair of long tusks § implanted in sockets, like those of the *Walrus*. The vertebræ, as in most of the extinct saurians, are sub-biconcave. This marvellous type of reptilian structure is perfectly unique.

* Cambridge Philosophical Transact., vol. vii. p. 355; Medals, p. 713.

† See Mr. Bain's Memoirs on the Geology of this region, and Prof. Owen's detailed descriptions of the several species of Dicynodon, in the 7th vol. of the Geol. Transact. 2nd series, 1845-57; and in the Descript. Catal. Foss. Rept. and Pisces, Roy. Coll. Surgeons, 1854, p. 80. See also *Medals*, vol. ii. p. 714, &c.

‡ This collection has been deposited in the British Museum; and several of the specimens have been perfectly cleared by Mr. Dew, and others will be exposed before long.

§ Hence the name *Dicynodon*, "two canine teeth."

The *Acrosaurus* is another extraordinary fossil reptile from the same locality. It has thirty or forty teeth on the alveolar ridge; and a broad process of the malar bone extending downwards over the side of the lower jaw, as in the Glyptodon (see p. 171). Prof. Owen has described specimens of the vertebræ of three other genera of great fossil Lacertia from the same peculiar South African formation. These are the *Massospondylus*, *Pachyspondylus*, and *Leptospondylus*; collected by Dr. Orpen, in the Drakenberg Mountains.*

14. ICHNOLITES, OR FOSSIL FOOTSTEPS. — Some years since, the attention of geologists was excited by the discovery of impressions of the footsteps of quadrupeds on the surface of the red sandstone† at Corncockle Muir, in Dumfriesshire.‡ The imprints resemble those made by the paws or pats of land-tortoises. Entire tracks of these imprints, indicating the slow progression of a four-footed animal, appear on some of the slabs. On one block of sandstone there were twenty-four consecutive impressions of feet, forming a regular track, with six distinct repetitions of the marks of each foot, the fore-feet differing from the hind-feet; the appearance of five claws was discernible in each fore-paw. The

* Descript. Catal. Coll. Surg. 1854, p. 97.

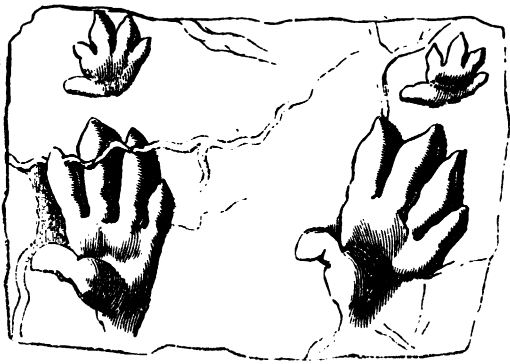
† The red sandstone of Corncockle Muir was formerly referred to the New Red Series; but the researches of Mr. Binney and Prof. Harkness have shown that the several patches of red sandstones in the South of Scotland, excepting that of Annan, are of Permian age. Quart. Journ. Geol. Soc. vol. xii. pp. 138, and 254.

‡ Account of the Marks of Footsteps of Animals found impressed on Sandstone; by the Rev. H. Duncan, D.D., Edinburgh, Trans. Royal Soc. vol. xi. 1828. Numerous fossil foot-tracks from the quarries at Corncockle Muir are beautifully illustrated, of natural size and colours, in Sir W. Jardine's magnificent "Ichnology of Annandale;" and Prof. Harkness has described others in the "Annals of Nat. Hist." for 1851. In Mr. Morris's "Catalogue of British Fossils," 1854, p. 355, is a very perfect Synopsis of all the fossil foot-prints hitherto found in the British strata: but "Permian" must be substituted for "Trias" in the case of the Corncockle and Dumfries specimens.

observations already offered on the ripple-marks on sandstone (see p. 382) render it unnecessary to explain the preservation of imprints of this nature. Similar appearances have since been observed on the Triassic sandstone near Stourton and Runcorn in Cheshire, and in several places in Germany, but no bones of tortoises have been discovered in these strata.

A discovery of a like nature was made soon afterwards in the New Red sandstone near Hildburghausen, in Saxony. Numerous imprints of the feet of some large quadrupeds, having the fore-paws much smaller than the hinder, were observed on the exposed surfaces of some slabs of rippled sandstone: and similar footsteps have been found in the quarries at Stourton, Taporley, and Lymm in Cheshire, at Annan in South Scotland, and near Warwick. These imprints are on the face of each successive layer of stone; and on some of the slabs not only are there foot-prints of various kinds of animals that walked over the stone when it was in the state of soft sand, but also the impressions of rain-drops. Some of the recently exposed surfaces present a blistered or warty appearance, being covered either with little hemispherical eminences, or with depressions; and these, upon an accurate investigation of the phenomena, prove to have been the effect of rain, which fell while the surface was soft and impressible. On many of the slabs the forms of the rain-drops and of the foot-prints appear in relief, being casts of the surface upon which the impressions were made; while on the clay corresponding hollows are apparent (as in *Lign.* 133).

Chirotherium.—The foot-prints found on the sandstones and shales above referred to are of various kinds; some appear to have been produced by small reptiles and crustaceans; but the principal markings are referable to some *large quadruped,* in which the fore-feet were much smaller *than the hinder* (*Lign.* 132). From the supposed resemblance of these imprints to the shape of the human hand, the name of *Chirotherium* was adopted to designate the animals which left these enigmatical "footsteps on the sands of Time." Since the discovery of the bones of gigantic Sauro-



LIGN. 132.—NATURAL CASTS OF THE FOOT-MARKS OF THE LABYRINTHODON (CHIROTHERIUM) AND CASTS OF SUN-CRACKS, ON SANDSTONE; FROM HILDBURGHAUSEN.

Fig. 1, 1, Impressions of the hinder feet. 2, 2, Imprints of the fore feet.
(One-eighth the natural size.)
[*The imprints in this example are not right and left, but are parts of two tracks.*]

batrachians in the same strata, it has been suggested that the footmarks were produced by some of the large Labyrinthodons; a conjecture highly probable, for the fore and hind feet of many of the frog-tribe are as dissimilar in size as those of the so-called Chirotherium.*

15. ORNITHOIDICHNITES, OR FOSSIL FOOTPRINTS RESEMBLING THOSE OF BIRDS. — In the United States of North America, a group of strata, which, as far as the imperfect

* See Dr. Buckland's "Bridgewater Treatises" for figures and further details. *A fine series of* specimens of Chirotherian imprints are in the *Brit. Mus. Collect. Petrifactions*, p. 63. See also Geol. Transact. 2 *ser. vol. vi. p. 537*, and Geol. Soc. Journ. vol. ix. p. 37.

evidence afforded by their fossils can show, appear to belong to the Triassic system, occur in the valley of the Connecticut river, stretching through the states of Connecticut and Massachusetts; and a band of similar deposits ranges from beneath the Palisadoes of the Hudson to the interior of Virginia.* The materials are red shale and argillaceous sandstone, with detached beds of conglomerate.† It is on the surface of the laminated argillaceous sandstones of this system, and principally in the valley of the Connecticut, that occur those mysterious characters on which the sagacity and unremitting labours of Professor Hitchcock have thrown so much light; ‡ but still the nature of the animals by which the foot-prints were made is involved in obscurity, for no vestiges of the skeletons of the bipeds, the lineaments of whose feet are so vividly apparent, have been discovered.§

The origin assigned to these markings was for a long while disputed, but Professor Hitchcock's interpretation is now generally admitted;

* When the fossils of these Virginian sandstones, shales, and coal-beds are taken in consideration, the peculiar group of strata above alluded to must be regarded as having much of the character of the Lower Jurassic series of the North British area. See above p. 519.

† Professor Henry Rogers' Address at the Meeting of the Association of American Geologists, May, 1844.

‡ The reader is referred to Professor Hitchcock's "Report on the Geology of Massachusetts," to Dr. Buckland's "Bridgewater Treatise," to the "American Journal of Science," Transact. Americ. Phil. Soc. new ser., and Trans. Amer. Acad. Arts and Sciences, for many interesting papers by Dr. Deane (who first drew Professor Hitchcock's attention to the subject) and other American naturalists; and to the "Medals of Creation," p. 768; and "Petrifactions," p. 64.

§ Reptilian remains occur in the Red Sandstones of North America, (namely, the Clepsysaurus, Centemodon, and Bathygnathus, Geol. Soc. Journ. vol. xii. p. 377). Dr. Emmons has described the bone of a bird from the Chatham coal-field, in Carolina, probably of nearly the same age; and numerous relics of reptiles (Dictyosaurus, Omosaurus and Rutiodon or Clepsysaurus, and Compsosaurus or Palæosaurus), and some small Mammalian jaws from beds of Permian (?) age. Americ. Geol. part vi. 1857.

though the discovery of bones of birds in strata of this epoch is required before the question can be regarded as determined. The number and variety of these footsteps are so considerable, that in 1853 Professor Hitchcock considered he had sufficient data to warrant their arrangement in numerous genera, comprising upwards of fifty species, varying in size from half an inch to twenty inches in length; the greater part being referable to bipeds; whilst about a dozen quadrupeds can be recognised, most of them with the hind-feet much larger than the fore-feet.* The abundance of foot-prints on the Connecticut sandstones is explained by supposing the strata to have originated from sediments deposited in a tidal estuary; and that various kinds of birds and reptiles frequented the low muddy shores, when the tide receded, in pursuit of worms and other prey; and that their footsteps were covered with a thin layer of silt at each reflux of the waves.

The following remarks of Dr. Deane will convey an idea of the colossal proportions of some of these imprints:—"I have in my possession consecutive impressions of a tridactylous foot which measures eighteen inches in length, by fourteen in breadth, between the extremities of the lateral toes . . . . . Each step will hold half a gallon of water, and the stride is four feet." The original bird must have been "four or five times larger than the African Ostrich, and, on this basis, could not have weighed less than 600 pounds . . . . . Every step the creature took sank deep into the stratum, and the sub-strata bent beneath the enormous load. If an ox walk over stiffened clay, he would not sink so deeply as did this mighty bird." †

Sir C. Lyell mentions having seen on the banks of the Connecticut river (at Smith's Ferry, near Northampton, eleven miles from Springfield) "a space several yards square where the entire surface of the shale was irregular and jagged, owing to the number of footsteps, not one of which could be traced distinctly, as when a flock of sheep have passed over a muddy road; but, on withdrawing from this area, the confusion gradually ceased, and the tracks became more and more distinct." ‡

Some fine slabs of the sandstone, covered with several tracks of bipeds of various sizes, collected by Dr. Deane, are deposited in the British Museum. A representation of

* See "Final Report on the Geology of Massachusetts," p. 477; "Elementary Geology," p. 155; and "Geology of the Globe," p. 98.

† Boston Journal of Nat. Hist. vol. v. p. 282.

‡ Travels in North America, vol. i. p. 254.

one of the small imprints of the natural size, with the s face of the stone marked with hemispherical pits produ by a shower of rain, is given in *Lign.* 133.

LIGN. 133.—FOOT-MARK OF A BIPED, AND IMPRESSIONS OF RAIN-DROPS; on Sandstone; Massachusetts (*nat. size*).
[*American Journ. Science*, vol. xlvi. p. 73.]

The enormous magnitude of some of the foot-prints w formerly deemed an insuperable objection to the interpre ation of these obscure vestiges adopted by the Americ naturalists; but the discovery of the bones of tridacty birds (*Moa*, see p. 129) in the alluvial deposits of N Zealand, some of which indicate a size equal to that of t most colossal of the fossil imprints, has removed that obj tion, and shown that in comparatively modern times, t earth was trodden by birds as gigantic as the bipeds that strode along the shores of the Triassic waters.

I must not, however, dwell longer on this inviting subject, and will only add, that, while offering my humble tribute of admiration to the sagacity and patience with which the subject has been investigated by Professor Hitchcock and others, and fully admitting the close resemblance of the bipedal fossil foot-prints to those of birds, I consider the following caution of Professor Owen to be deserving of the most serious attention: — "Foot-prints alone, like those termed 'Ornithichnites,' are insufficient to support the inference of the possession of the highly developed organization of a bird of flight by the creatures which have left them. The Rhynchosaur and biped Pterodactyles already warn us how closely the ornithic type may be approached without the essential characters of the Saurian being lost. By the Chirotherian Ichnolites we learn how closely an animal, in all probability a Batrachian, may resemble a pedimanous mammal in the form of its foot-prints." †

16. Triassic Mammal.—Before leaving the subject of the Trias, we must again allude to the "Bone-bed," ‡ so closely related to the Lias in England, but decidedly Triassic in character on the Continent. At Stuttgard, among other very interesting fossils, it has yielded to the researches of Dr. Plieninger two minute *mammalian* teeth (*Microlestes antiquus*). These have been described and figured in the "Nova Acta," § 1850, and in Sir C. Lyell's "Manual."

* The close resemblance of many of these North American foot-marks to those made by recent birds is most striking. Sir C. Lyell, in his "Travels in North America" (vol. ii. p. 168, pl. 7), has placed this correspondence, I might almost say identity, in a strong point of view, by giving figures of recent foot-marks of the Sandpiper on hardened red mud, from the Bay of Fundy; these specimens are now in the British Museum and the Geological Society's Collection, for comparison with the fossil imprints.

† Brit. Assoc. Rep. 1841, p. 203. ‡ See above, p. 524.

§ Nov. Act. Cæs. Acad. Nat. Cur. vol. xxii. p. 902, pl. 71, fig. 14 and 15.

Taken in connection with the little fossil Mammals from Stonesfield and Purbeck,* and with Dr. Emmons's specimens from North Carolina (which last are probably more ancient than the *Microlestes*), these afford evidence of the existence of a marsupial fauna during the secondary epoch.

17. THE PERMIAN FORMATION.—The group of strata thus designated was formerly termed the Lower New Red, or Magnesian-limestone formation. It comprises the Bunter-Schiefer, Zechstein, Kupfer-Schiefer, and Rothliegendes of the Germans; that is, all the deposits intervening between the Carboniferous and the Triassic systems. Like the Trias, it consists of a triple series of deposits, namely, 1. Conglomerates, sands, and clays; 2. Limestones; 3. Sands and clays. The clays, sandstones, and conglomerates are more or less coloured by oxides of iron, and are associated with pyritous shales, gypsum, salt, &c.; some of the limestones, containing a large proportion of magnesia, are known as *Dolomite*,† and others, retaining a strong animal odour, are termed *Stinkstein*. This system being palæontologically characterized by a peculiar type of organic remains, and by the absence of nearly every species that occurs in the newer or overlying formations, the Permian is ranked as the last, or uppermost, of the palæozoic system. (See Synopsis, p. 203.) ‡

* See above, p. 394 and p. 508.

† The crystalline calcareo-magnesian rock (termed *Dolomite*, from M. Dolomieu, who first pointed out its mineralogical character) has the same external aspect as granular limestone; but, instead of being a pure carbonate of lime, contains from 45 to 60 per cent. of carbonate of magnesia.

‡ M. Pictet has shown, in the 4th volume of his new edition of "Paléontologie," pp. 577 and 579, that the proportion of *generic* forms passing from the earlier periods to the Permian is 56 per cent.; whilst of those received by the Trias from older periods the proportion is only 33 per cent. He considers that the palæontological difference of the Carboniferous period and the Permian may be approximatively indicated by "53," whilst "60" may indicate that between the Permian and Trias.

In the central part of England, and extending from the neighbourhood of Nottingham to the south-eastern extremity of Northumberland, red marls, sandstones, and breccias form the lowermost Permian strata, and are regarded as the equivalents of the *Rothliegendes* of Germany; a term applied to a group of red sandstones and conglomerates, accompanied with porphyry and other old volcanic rocks, that constitutes the base of the Permian series of the Continent. Upon these lower red sandstones are magnesian limestones, upwards of 300 feet in total thickness, corresponding with the *Stinkstein*, *Rauchwacke*, and *Zechstein* of Germany.

In the North of England the Permian formation is well developed, having four or more distinct members, and attaining about 1000 feet of thickness.* In the Midland Counties, the calcareous element is almost absent in the series, sandstones predominating, and, with the associated marls, making a thickness of upwards of 1500 feet.† Still further south and west the formation rapidly attenuates, and is represented by thin bands of sandstone and conglomerate, or breccia.

In Somersetshire, and the adjacent country around Bristol, beds of conglomerate,‡ formed of the debris of older rocks, held together by a

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* Mr. Binney has described the Permian beds of the North-West of England (Mem. Lit. Phil. Soc. Manchester, vols. xii. and xiv.) as consisting of, 1. (at top) Red and variegated gypsiferous marls (300 ft. thick); 2. Magnesian limestone (10 ft.); 3. Conglomerate (350 ft.); 4. Red sandstones and marls (500 ft.). Below these is the red and variegated sandstone of Whitstable, which Mr. Binney is disinclined to regard as Permian.

In the "Annals Nat. Hist." 2 ser. vol. xix. p. 33, &c., Mr. R. Howse describes the Permian series in Durham as consisting of, 1. (at top) Reddish sandstone (Lower Bunter?); 2. Upper yellow limestone (100 ft. thick); 3. Botryoidal limestone (150 ft.); 4. Cellular limestone and shell-limestone (150 ft.); 5. Compact limestone and conglomerate (200 ft.); 6. Marl-slate (3 feet). These are underlaid by sand and red sandstone, which, containing fish-remains and plants of species proper to the Coal-measures, are referred by Mr. Howse to the Carboniferous series, though hitherto regarded as the equivalent of the Roth-liegendes.

† See Mr. Jukes's description of the structure of the South Staffordshire Coal-field, in the "Records of the School of Mines," vol. i. p. 160; and Prof. Ramsay's Notice of the Permian rocks near Bridgenorth, Quart. Geol. Journ. vol. xi. p. 188.

‡ Mem. *Geol. Surv. vol.* i. p. 239. See Mr. Sanders's observations on *the possibly Triassic* age of this conglomerate, Brit. Assoc. 1849, Sect. p. 65.

dolomitic cement, are spread unconformably over the carboniferous strata, filling up the irregularities and hollows of the surface of the mountain-limestone, &c., occasioned by the dislocations and fractures which those rocks had sustained by disturbing forces, before the deposition of the Permian deposits. This conglomerate is made up in great part of pebbles and fragments of mountain-limestone, millstone-grit, coal-shale, and other detritus of the strata on which it reposes; and contains fractured and water-worn bones of Saurians, teeth of fishes, &c. It is well displayed, overlying the coal-strata and mountain-limestone, near Clifton in the valley of the Avon, and at Portishead, and other places in the vicinity.*

In Devonshire is a peculiar conglomerate or breccia, referred by Sedgwich and De la Beche to the Permian formation, and the structural characters of which point to the probable fact of eruptions of lava having been locally discharged into the Permian sea, and to have cemented together the water-worn materials, so as to form a *trap-conglomerate;*—such, at least, seems to have been the origin of the amygdaloidal trap, as it is termed, in the vicinity of Exeter.† A few miles to the south of that city, masses of a rock of this kind are interposed between beds of sandstone; the general appearance of the stone is that of a granular rock, somewhat loosely compacted, of a purplish-brown colour, interspersed with minute portions of calcareous spar, mica, and indurated clay tinged by copper or manganese. It is full of small ovoidal cells, which are either filled or lined with manganese, calc-spar, or jasper; a structure termed in geology *amygdaloidal*, or almond-like: the substance of the rock is an earthy felspar.

Another interesting feature of the Permian series is a breccia, or conglomerate of pebbles and angular stones imbedded in a red marly matrix,‡ belonging to the lower portion of the series, and occurring over a large extent of country in Worcestershire and South Staffordshire. It consists of more or less worn fragments of quartz, slates, traps, sandstones, and fossiliferous rocks, many of which are traceable, in Prof. Ramsay's opinion, to parent-rocks in the Welsh border-country, sometimes 50

* The dolomitic conglomerates near Bristol and on the Mendip Hills are ably described by Buckland and Conybeare, Geol. Trans. 2nd ser. vol. i. p. 291.

† Geology of England and Wales, p. 294; Geol. Proceed. vol. ii. p. 196; De la Beche's Report, Devon, &c., p. 203.

‡ Phillips, Mem. Geol. Survey, vol. ii. part i. p. 112; Ramsay, Quart. Geol. Journ. vol. xi. p. 155, and Notices, Roy. Instit. April 24th, 1857.

miles distant. From this circumstance, and on account of the size, angularity, smoothness, and striated appearance of many of the stones, Prof. Ramsay considers that they could have been transported and brought together only by the agency of floating ice; just as the boulders of the Pleistocene drift * are acknowledged to have been borne from great distances and accumulated by means of icebergs and coast-ice.

18. MAGNESIAN LIMESTONE OR DOLOMITE.—The magnesian limestone of England is regularly stratified, and, when recently exposed, has a granular or saccharine structure, with a glimmering lustre; the colour is generally either a pale-fawn, salmon, or yellow, from hydrate of iron,—or red, from oxide of iron. The hard varieties yield some of the best building-stone in England.†

In many places the limestone occurs in large concretional and botryoidal masses; the concretions varying from the size of small peas to that of large cannon-balls; and these are often grouped together like bunches of grapes, or masses of chain-shot. On the coast of Durham, the whole cliff is made up of large concretional clusters, resembling piles of cannon-balls. This phenomenon is best seen near Sunderland, and along the shore near Marsden and Black Rocks; where it is associated with other curious and interesting modifications of concretional action.‡ These masses offer a beautiful illustration of spheroidal structure, superinduced on stratified detritus *after its deposition;* for the sedimentary laminæ pass through the globular concretions uninterruptedly. The limestone is commonly traversed by veins and strings of carbonate of lime, and occasionally contains hollow spheroids of calcareous spar and crystals of sulphate of strontian and barytes. Galena, or sulphide of lead, sulphide of zinc, calamine, and carbonate of copper, also occur; and some veins of galena in the Mendip Hills have yielded profitable returns.§

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* See vol. i. p. 217, &c.

† The New Houses of Parliament at Westminster are constructed externally of magnesian limestone, from quarries at North Anstone in Yorkshire, and near Worksop in Nottinghamshire.

‡ See an admirable Memoir, "On the Geographical Relations and internal structure of the Magnesian Limestone," by the Rev. Adam Sedgwick, Geol. Trans. 2nd Ser. vol. iii. p. 37

§ Geology of England and Wales, p. 304.

19. PERMIAN OF GERMANY AND RUSSIA. — In Thuri gia * and Saxony the magnesian limestone (*Stinkstein, Rauc wacke*, and *Zechstein*) is largely developed, and is underla by a thin band of dark bituminous shales highly charg with copper-pyrites, which is termed the *Kupfer-Schief* These shales have long excited the attention of naturalis from the number and variety of the fossil fishes they contai and the peculiar mineralized condition in which these reli occur; specimens from Eisleben near Mansfeld,† a cel brated productive locality of these ichthyolites, are to found in almost every museum in Europe. These fish which principally belong to the genera *Palæoniscus*, *Pyg pterus*, and *Platysomus*, are generally in a contorted stat apparently the effect of violent convulsions attendant their sudden destruction. The appearance of a violent dea presented by these Ichthyolites is regarded by M. Agass as entirely deceptive: and he states that the bent and twist condition of the body is solely attributable to muscular co tractions during decomposition after life was extinct.‡ T specimens are splendidly invested with copper-pyrites, a their scales often have the appearance of burnished gol The bodies of the vertebræ of the spinal column are almc always wanting.§

The researches of Sir R. Murchison and his colleague have shown that the Permian system in European Russ

* The elaborate memoir, by Sir R. Murchison and Prof. Morris, the Palæozoic rocks of the Thuringerwald and the Harz, comprises clear exposition of the relations of the Permian rocks of these distric Quart. Journ. Geol. Soc. vol. xi. 420, &c.

† An account of this locality, and a geological Map of the distr west of Halle, are given by M. Paul Herter in the Transact. Nat. Hi Soc. of Halle, vol. iv.

‡ Recherches sur les Poissons Fossiles, tome ii. p. 70.

§ Medals, p. 601.

‖ Russia in Europe and the Ural, chap. viii.

consists of strata similar to the great group of red and variegated marls, sandstones, conglomerates, and associated magnesian limestones, of England and Germany, and reposes on the Carboniferous deposits. It extends over an area 4,000 miles in circumference; a space equal to twice the surface of the kingdom of France.

The Permian deposits of Russia, which occupy so vast a region to the east of the river Volga, namely, in the governments of Kasan, Viatka, Perm, and Orenburg, are composed of calcareous flagstones, with gypsum, red and green grits and shells (with copper-ores and plant-remains); magnesian limestones and marlstones; conglomerates, red and green sandstones, &c. It is worthy of remark, that the plant-remains, the fossil reptiles, and the coppery beds are in Russia found frequently above the great bands of limestone, whilst in Germany, on the contrary, they occur below the limestones.

20. Fossils of the Permian System.—The fauna and flora of this formation are invested with peculiar interest, because they present us with the last term of the palæozoic creation, that ancient type of organic life which prevailed from the earliest periods, affording any evidence of the presence of living things in the waters or upon the surface of our planet. For the two grand changes in the organic world, as demonstrated by fossil remains, are unquestionably those which separated the palæozoic ages from the secondary, and the latter from the tertiary. There are no less than 166 species of fossil plants and animals from the Permian deposits which have been accurately determined; of these 148 are unknown in any other formation.

Plants.—The plants are in great part referable to genera common in the coal-measures, but very rare or altogether wanting in the formations above the Permian; for example, species of *Lepidodendron*, *Nœggerathia*, *Odontopteris*, *Pecopteris*, *Sphenopteris*, and *Calamites*, indicating a continuation of vegetable life of the same nature as that which prevailed during the Carboniferous era.

Near Chemnitz, in Saxony, silicified stems of tree-ferns (*Psaronites*) occur; numerous trunks of coniferous trees (*Araucarites*) are common in the Rothliegendes at Kyfhausen; and other plant-remains are met with near Zwickau and elsewhere in the same kingdom.* At Allesley,† near Coventry, silicified trunks of coniferous trees have been found in the Permian sandstone (formerly referred to the New Red); and other plant-remains, such as *Caulerpites*, *Breea*, *Lepidodendron*, and *Calamites*, are mentioned by Professor Ramsay‡ as having also occurred in these beds in Warwickshire.

21. INVERTEBRATA OF THE PERMIAN.—The *Radiaria*, *Mollusca*, and *Articulata* occurring fossil in the Permian rocks of England and Ireland have been described with much care by King,§ Howse,‖ and Kirkby,¶ who enumerate upwards of 130 species. Tragos, Dentalina, Spirillina, Calamopora, Spirorbis, Cythere, Prosoponiscus, Fenestella, Strophalosia, Monotis, Bakevillia, Schizodus, Turbo, Chemnitzia, Pleurotomaria, and Nautilus are the principal genera.**

22. FISHES OF THE PERMIAN.—The fishes of this system comprise beween forty and fifty species, belonging to sixteen or seventeen genera:†† most of these genera and a few of the species occur also in the Carboniferous series of rocks. All

* Gutbier's Verstein. Permisch. Syst. Sachsen; and Geinitz's Steinkohl.

† Geol. Proceed. vol. ii. p. 439.

‡ Quart. Geol. Journ. vol. ix. p. 198. Prof. King enumerates seven Permian plants in his Monograph, Pal. Soc. 1856.

§ Monograph, Palæontog. Society, 1850; and Ann. N. H. vol xvii.

‖ Annals Nat. Hist. 1857, vol. xiii. pp. 33, 304, and 463.

¶ Quart. Journ. Geol. Soc. vol. xiii. p. 213.

** A comparative table of the fossil animals of the Permian system, as far as known in 1845, is given in the "Geology of Russia," vol. i. p. 221. Schlotheim, Reuss, Schauroth, &c. have described the Permian fossils of Germany.

†† About seven of these genera occur in the Permian rocks of England.

the ichthyolites of this group possess that remarkable modification of the tail which we have already mentioned as having been of excessive rarity in the fishes of the secondary and tertiary seas, as well as in those that inhabit the existing ocean; in which the Sharks and Sturgeons are almost the only representatives of this palæozoic type. The caudal fin is universally heterocercal; that is, the vertebral column is prolonged at its extremity into the upper lobe of the tail.* One of the most striking ichthyological features of the Permian deposits is the prevalence of fishes of the genus *Palæoniscus*,† of which several species abound in the Permian and Carboniferous strata of England, Europe, and North America. These fishes belong to the heterocercal ganoids, and are covered with rhomboidal scales, which in some species are very small, and in others large. In one locality near Dungannon, in Ireland, a small species is sometimes found in groups of more than two hundred individuals on a slab of stone not exceeding two feet square. One species only of the genus (*Palæoniscus superstes*) has been identified in the Trias.

23. Reptiles of the Permian.—The earliest certain indications of the existence of reptiles on our globe have been obtained from the deposits of the Carboniferous and Devonian formations; for neither teeth nor bones of animals of a higher order than fishes have been discovered in any of the more ancient formations.

The *Archegosauri* of Saarbruck, the *Dendrerpeton* and *Baphetes* of Nova Scotia, the *Parabatracus* of Carluke, and

* See figure of the restored figure of the *Amblypterus* (*fig.* 183, p. 770) of the Carboniferous system, in which *a* marks the prolongation of the vertebral column into the upper lobe of the caudal fin: this fish is a good illustration of the *heterocercal* type; and the *Lepidotus* of the Wealden (*Lign.* 105, p. 423) affords an example of the *homocercal* fish.

† Professor Sedgwick's memoir, *Geol. Trans.* 2 ser. vol. iii. is accompanied by numerous figures of Palæonisci (pl. 8 and 9). See also Agassiz, Poiss. Foss. vol. ii., and King's *Monogr.* Perm. Foss. 1850.

some lately discovered reptilian footprints in the coal-shale of Deane Forest, well represent the reptilian forms of the Carboniferous period, when evidently there were many cold-blooded quadrupeds coeval with the luxuriant flora of the coal.* The little *Telerpeton Elginense* † and some probably chelonian footprints remain as evidences of the Devonian reptiles—the oldest yet known; and in Pennsylvania reptilian foot-tracks occur both on the Carboniferous and the Devonian rock-surfaces.‡

In some of the Permian rocks reptilian remains are not unusual; and indeed they form important characteristics of these deposits. The bituminous Kupferschiefer of Thuringia has yielded the *Protosaurus* (the "fossil monitor of Thuringia," for a long time the oldest-known reptile); the copper-bearing Permian conglomerates of Russia are sometimes rich with bones of reptiles; in the dolomitic conglomerate of Somersetshire the remains of large thecodont § lizards have been found; and similar forms occur, according to Dr. Emmons,‖ in the Permian strata of the Chatham coal-field in North Carolina.

Thecodontosaurus and *Palæosaurus*.—These British fossils were obtained from Redland, near Bristol, and are preserved in the museum of that city; they consist of jaws, teeth, vertebræ, and bones of the extremities, referable to two genera of saurians, named as above by Dr. Riley and Mr. Stuchbury, by whom they were first made known.¶ The teeth are pointed, compressed laterally, trenchant, and finely serrated on the edges. These reptiles, in their thecodont type of dentition,

* Medals, vol. ii. p. 748. † Medals, vol. ii. p. 720.

‡ American Journ. Science, new ser. vol. i. p. 268, and vol. ii. p. 25; and Medals, vol. ii. p. 749.

§ *Thecodont;* i. e. having the teeth implanted in distinct sockets, as in the crocodile.

‖ American Geology, part 6, 1856, p. 85.

¶ *Geological* Transactions, 2nd ser. vol. v. p. 359, pl. 29 and 30.

biconcave vertebræ, double-headed ribs, and proportionate size of the bones of the extremities, are nearly related to the Teleosaurus of the Oolite (p. 532); but combine a lacertian form of tooth and structure of the pectoral arch with these crocodilian characters: and the bodies of the vertebræ have a series of ventricose excavations for the spinal chord, instead of a cylindrical canal. The reptile found in the copper-shales, and termed the "Thuringian fossil monitor" (*Protorosaurus*), appears to be related to the thecodont saurians of Bristol. The spinous processes of the dorsal vertebræ are described as remarkably high, and the caudal vertebræ are characterized by double diverging spinous processes.

Rhopalodon.—Fragments of jaws with teeth, and a few detached teeth, of thecodont reptiles, apparently related to the Bristol saurians, are amongst the reptilian remains obtained from the Permian deposits of Russia. They are figured and described by M. Fischer under the generic name of Rhopalodon.*

From what has been advanced respecting the fossils hitherto found in the Permian formation, it appears that the organic remains are distinct from those of the contiguous upper system or Trias, and present a close relation to the types which characterize the lower deposits.

24. Reptiles.—As the multitude of reptilian forms with which we have been surrounded in our progress through the faunas of the secondary epochs disappears with the Triassic epoch, and as the reptiles of the Palæozoic system are comparatively limited in number, I will here offer a few general observations on this class of animals, that the unscientific inquirer may be enabled to comprehend the inferences that arise from the facts submitted to his notice.†

* Sur le Rhopalodon, genre de Saurien Fossile du versant occidental de l'Oural; par G. Fischer de Waldheim, Moscou, 1841, and Bullet. Soc. Nat. Moscou, 1845.

† See "Medals of *Creation*," *vol. ii.* chap. xvii., for a fuller consider-

All animals possess organs by which a certain change is effected in the circulating fluid, to refit it for the purposes of nutrition. Mammals, birds, and reptiles are furnished with an apparatus of areolar and vascular tissue, termed lungs, by which a large surface of the blood is brought in contact with the air; in aquatic vertebrates (fishes) this apparatus is the gills, which are organs fringed with innumerable processes, supplied by myriads of vessels, disposed like net-work, by which the blood is exposed to the action of aerated water, oxygen absorbed, and vitality maintained. In Reptiles, the respiratory organs are less developed than in any of the other vertebrated animals, but they all possess lungs, and are capable of breathing air: and some have gills, and perform aquatic respiration. The heart, which is generally three-chambered, is so disposed, that at each contraction only a portion of the volume of blood is sent to the lungs; hence the action of oxygen on the circulating fluid is in a less degree than in any of the mammals, birds, or fishes. As animal heat, the susceptibility of the muscles to nervous influence, and even the nature of the skin, are dependent on respiration, the temperature of Reptiles is low and their muscular powers are, on the whole, very inferior to those of Birds or Mammals: requiring no integuments, as hair, wool, or feathers, to preserve their temperature, they are merely covered with scales, or have a naked skin. As they can suspend respiration without arresting the course of the blood, they dive with facility, and remain under water for a long period without inconvenience. Some are viviparous, others are oviparous, laying their eggs, which they

ation of the subject. For a comprehensive and philosophical view of this department of Palæontology, the English reader should study the memoirs of Prof. Owen in the British Association Reports, 1839, 1840, and 1841; and his Monographs published by the Palæontographical Society. Pictet's 'Paléontologie,' also, should be consulted, both for the details of the fossil reptiles, and for references to other authors.

never hatch, on the sands or banks. They present great diversity of form; some are extremely elegant, others grotesque and hideous, and many have dermal processes of the most fantastic shapes. Their habits are exceedingly variable; some are agile, others torpid; all hibernate, or rather relapse periodically into a state of dormancy, whether produced by cold, drought, or excessive moisture. Their peculiar structure enables them to endure long abstinence, to an extent impossible to other races of animals. Their seasonal habits, or, in other words, alternate periods of activity and repose, are in accordance with the sudden evolutions of the seasons; they are dormant when nature does not need their agency, and rouse into activity when required to repress the redundancy of those vegetables or animals which constitute their food; a property strikingly manifest in the species of hot climates; thus exhibiting an admirable adaptation to the peculiar conditions of existence which they are destined to fulfil. Some are herbivorous, others carnivorous, and many prey on insects; their powers of progression are as various; some orders, though destitute of fins, wings, or feet, bound along the ground with great agility (the Serpents); others walk or swim; while a few are capable of flight.*

25. Turtles, or Chelonian Reptiles.—In Turtles the want of active faculties is compensated by their passive means of resistance. They have no weapons of offence, but are enclosed in a panoply of armour formed by the expansion of the costal plates above, and by the ossified plastron beneath.† The carapace, or buckler, constituting the shell that spreads over the back of the turtle, is composed of bony plates continuous with the ribs, which, instead of being separated by intervals, as in other animals, are united together by the

* The *Draco volans*, or Flying Dragon.

† See Owen, "On the Carapace and Plastron of Chelonian Reptiles." *Phil. Transact.*, 1849, p. 151.

costal plates. Thus in the delicate and agile form of the Serpent, and in the heavy and torpid mass of the Turtle, the same general principle of structure prevails, and, by a simple modification, the skeleton is adapted for beings of very dissimilar forms and habits. The *Testudinata*, or turtles, like the other large reptiles, are essentially confined to torrid and temperate regions. The fresh-water species are capable of bearing a higher latitude than the terrestrial: upon the whole the utmost range of this order appears to be from 54° N. lat. to about 40° S. lat.* The fluviatile species, or *Emydes*, are carnivorous, feeding on frogs and small animals; those of the genus *Trionyx* (*three-claw*) are African or Asiatic, with the exception of the *Trionyx ferox*, which inhabits the hot regions of America. They live upon food which is found at the bottoms of rivers; in the stomachs of several procured from the Ganges, by Col. Sykes, were large quantities of mussels, the shells of which were broken into small angular fragments. The fossil bones of a Trionyx-like animal (*Tretosternon Bakewelli*) from Tilgate Forest, were imbedded in a mass of mussel-shells; a collocation which might be expected in a fluviatile deposit. The form of the ribs and other parts of the skeleton differs in the Chelonians of the land, marshes, rivers, and the sea respectively, so that the fossil bones can, for the most part, be readily referred to the respective groups.

Fossil Tortoises and Turtles.†—The earliest indications of the existence of reptiles on the surface of our planet are supposed to be those of Chelonians; the imprints of the feet or pats apparently of a land-tortoise occurring on a slab of Devonian sandstone in Morayshire;‡ and similar footprints have been found in the millstone-grit of Cheshire,§ and are

* "The Testudinata," by Thomas Bell, 1 vol. folio; one of the most splendid works on Natural History that has appeared in this country.

† Medals, vol. ii. p. 726. ‡ Quart. Geol. Journ., vol. viii. p. 97.

§ *Ibid.* vol. xii. p. 350.

of more frequent occurrence in the Permian sandstone of Dumfriesshire,* and the Triassic beds at Stourton and Runcorn, in Cheshire. Throughout the Oolitic, Wealden, and Cretaceous epochs, Chelonians abounded; and from the most ancient Tertiary to the present time the four groups of this order of reptiles have flourished. Their remains, in great plenty and of prodigious size, are associated with those of the Sivatherium, &c., in the Sub-Himalayas; and with those of Mastodons in the Burmese empire, of Palæotheres in the French, Swiss,† and Isle of Wight tertiaries, and with fruits of tropical plants in the Isle of Sheppey; their bones and eggs are daily imbedded in the recent coral-sand of the Isle of Ascension. The remains of living species of Indian land-tortoises are said to be collocated with the bones of extinct miocene mammalia in the Sewalik hills.‡

26. Crocodiles.—This family of loricated or mailed saurian reptiles contains the only living types that at all approach in magnitude the colossal forms of the secondary epochs. The Egyptian Alligator, as is well known, attains a large size; and the long and slender-beaked crocodilian reptile of India, the Gavial (or Garial) of the Ganges, sometimes reaches a length of nearly thirty feet. The peculiar character of the teeth of these animals, and their mode of increase and renovation, have already been pointed out (p. 429). The vertebræ, or bones of the back, are concavo-convex; *i. e.* united to each other by a ball-and-socket joint, the convexity being behind. Some of the fossil crocodiles of the tertiary also have this structure of the spinal column; but in every crocodilian of the secondary formations, the articulating surfaces of the vertebræ are either flat or concave, except in one genus (*Streptospondylus*§), in which the vertebræ are convexo-concave, *i. e.* the convexity is directed forwards: a position the reverse of the ordinary type. Reptiles of the crocodilian

* Jardine's Ichnology of Annandale. † Pictet and Humbert's Monog.
‡ Falconer and *Cautley*. § Medals, p. 680.

order, but belonging to several extinct genera, swarmed throughout the whole of the secondary and tertiary epochs. As the living crocodilians frequent fresh water, the remains of animals of this type indicate the existence of countries watered by streams and rivers, or abounding in lakes: but the modification of the spinal column, so prevalent in the ancient forms, may, perhaps, be referable to a marine rather than to a terrestrial condition of existence, in some of these extinct saurians.

27. ENALIOSAURIANS, OR MARINE LIZARDS.*—*Ichthyosaurus* (*Fish-like Lizard*).—In the lias of the west of England, teeth, vertebræ, and other parts of the skeletons of reptiles, which were supposed to be related to the Crocodiles, had for many years excited attention; but until 1814, when a considerable collection, from Dorsetshire, formed by Mary Anning, was sold in London, no accurate investigation of these interesting relics had been attempted.† Subsequently a great number of skeletons have been found, numerous memoirs published, and the form and structure of the originals thoroughly investigated. Many beautiful specimens are figured and described in the splendid work of Mr. Hawkins, whose unrivalled collection of these remains is now deposited in the British Museum.‡ The bones of reptiles so abundant in the Lias are chiefly referable to two genera; the one called *Ichthyosaurus* (by Mr. König), to denote its relation to fishes and reptiles; the other, *Plesiosaurus* (so named

* Medals, p. 663.

† See No. I. of Charlesworth's "London Geological and Palæontological Journal," for an account of the sale of this collection.

‡ "Memoirs of Ichthyosaur and Plesiosaur;" by Thomas Hawkins, folio, with Plates, 1838; and "Book of the Great Sea-dragons," folio, with Plates, 1840. Fully to realize the external form and general character of the Ichthyosauri and Plesiosauri, the student must visit the Crystal Palace Gardens, and make himself acquainted with Mr. Waterhouse Hawkins's life-sized models of these extinct sea-reptiles; smaller models of which also are obtainable for study in the cabinet.

by Mr. Conybeare), to indicate that it approached nearer than the animals of the other genus to the Lizards, or Saurians.

The Ichthyosaurus had the beak of a porpoise, the teeth of a crocodile, the head and sternum of a lizard, the paddles of a cetacean, and the vertebræ of a fish. This restoration (*Lign.* 134) shows its general configuration, as demonstrable from the skeleton; from the peculiarity of the terminal vertebræ of the tail, Prof. Owen concludes that the original had a strong vertical tail-fin.* There are many species, some of which are of a magnitude equal to that of young whales. The teeth are conical, sharp, and striated, resembling those of crocodiles in the power of reproduction, but differing in the number, situation, and mode of regeneration: one species

LIGN. 134.—RESTORED FIGURE OF THE ICHTHYOSAURUS.

has 110 in the upper, and 100 in the lower jaw; they are arranged in a deep furrow or groove, not in sockets, and were retained only by the integuments. The orbit is very large, and the sclerotic or outer coat of the eye is made up of thin bony plates, arranged round the central opening or pupil, as in the owl and other birds; a mechanism by which the power of the eye is materially increased, and vision adapted to near or remote objects at will. The bones forming the sternum, or chest, which protect the organs of respiration, are strong, and largely developed,† and the sternal arch offers a remarkable correspondence with that of the Ornithorhyncus of Australia.

* *Geol. Trans. 2nd ser. vol.* v. p. 511. † Medals, p. 667

Like turtles, the Ichthyosaurus had four paddles, comp of numerous bones enveloped in one fold of integumen as to form an entire fin, as in the cetacea ;* the fore-pa are large, and in some species consist in one hundred b (*Lign.* 135) ; the hinder pats are smaller, and contain thirty or forty. The internal structure of these instrum therefore resembles that of the paws of turtles ; and (even the case in the fin of the Porpoise) the same elem

1.

2.

LIGN 135.—PADDLES OF THE ICHTHYOSAURUS AND PLESIOSAURUS, IN LIAS SH FROM LYME REGIS.

Fig. 1. Left fore-paddle of the Ichthyosaurus.
Fig. 2. Left fore-paddle of the Plesiosaurus.

(One-eighth the natural size.)

of an arm are found as in the quadrupedal mammalia, v *humerus*, *radius*, *ulna*, and *phalanges*. The nostrils, whic

* The soft integuments of the paddle are occasionally preserved the figure of a beautiful example from Barrow-on-Soar, Geol. T *2nd ser. vol. vi. pl.* 20, and Medals, p. 669.

Crocodiles are situated at the extremity of the beak or muzzle, are in the Enaliosauri placed, as in the Cetacea, beneath the orbits. The vertebræ are somewhat hourglass-shaped, but less so than in the sharks and other fishes; the spinal column admitted of the utmost freedom of motion, while in the neck the vertebræ connecting the head to the spinal column are anchylosed, and have supplementary bones to increase the strength, and diminish motion.* The general figure of the Ichthyosaurus must have been that of a Grampus or Porpoise, with four large paddles. The teeth prove it to have been carnivorous; the paddles, that it was aquatic; the scales, bones, and other remains of marine fishes constantly found in the abdominal cavities of the skeletons, and in the coprolites,† that it was an inhabitant of the sea. Its skin appears to have been naked, or at least destitute of scales.‡

28. The Plesiosaurus.§—The discovery of a remarkable specimen, by Miss Anning, enabled Mr. Coneybeare at once to establish the characters of that extraordinary extinct marine reptile, the Plesiosaurus, which differs from the Ichthyosaurus in the extreme smallness of the head, enormous length of the neck, and other osteological peculiar-

* Memoir on a Peculiarity of Structure in the Neck of the Ichthyosaurus, by Sir P. M. de Grey Egerton. Geol. Trans. 2nd ser. vol. v. p. 187.

† The *Coprolites*, or fossil excrements, of Ichthyosauri (the true nature of which was first ascertained by the sagacity of the late Dean of Westminster) are found in profusion in the clays and marlstones of the Lias; often occupying the abdominal cavity of the skeleton (see Dr. Buckland's Bridg. Treat., p. 190, pl. 15); and the state of preservation of these peculiar bodies is such, as to show not only the nature of the food of these reptiles, but also the dimensions, form, and structure of the stomach and intestinal canal. The coprolites of the fishes of the chalk often afford like indications. See above, p. 358; and Medals of Creation, p. 621.

‡ Relics of the skin occur in a fossil state. See Buckland's Bridgewater Treatise, Plate 10, fig. A. 1, 2, 3, 4; Mr. Cole's paper on the skin of the Ichthyosaurus, Geol. Journal, vol. ix. p. 79; and Mr. C. Moore's remarks on the subject, Report Brit. Assoc., 1856, p. 69.

§ Medals of Creation, p. 671.

ities.* The neck, which in most animals is composed of five vertebræ, and in the extreme recent example, the Swan, does

LIGN. 136.—RESTORED FIGURE OF THE PLESIOSAURUS.

not exceed twenty-four, here consists of from twenty to forty; and its length is sometimes equal to that of the entire body and tail. This reptile combines in its structure the head of a lizard, with teeth implanted in sockets like the crocodile, —a neck resembling the body of a serpent,—a trunk and tail of the proportions of those of a quadruped,—with paddles like the turtle (*Lign.* 135, *fig.* 2). The vertebræ are longer and less concave than in the Ichthyosaurus, and the ribs, being connected by transverse abdominal processes, present a close analogy to those of the Chameleon.

The collection of Mr. Hawkins, now in the British Museum, contains a skeleton eleven feet long, and so nearly perfect, that the entire form of the original creature may be completely restored. The late Dean Coneybeare compared the Plesiosaurus to a turtle stripped of its shell, and thought it probable, from its long neck presenting considerable impediment to rapid progress in the water, that it frequented the coast, and lurked among the weeds in shallow water. As it is evident that it must have required frequent respiration, it probably swam on or near the surface, and darted down upon the small fishes on which it preyed.

Ichthyosaurs and Plesiosaurs have been found throughout the secondary strata, from the Lias to the Chalk inclusive; with the exception of the Wealden, in which no traces of

* *In the sternum* of the Plesiosaurus the coracoid bones have their *greatest development.* Medals, p. 667, fig. 213.

Ichthyosauri have been discovered. Lyme Regis is the most celebrated locality in England, but the remains of numerous species of both genera have been discovered in many places in this country and on the Continent, in the Oolite and Lias. The British species of the Enaliosauri known and described by Professor Owen, amount to about twelve of the Ichthyosaurus, and nearly twenty of the Plesiosaurus.* A group of Reptiles, nearly related to the Enaliosaurians, but distinguished (under the name of *Simosauri*) chiefly by osteological peculiarities of the skull, are found in the Muschelkalk and other strata of the Trias in Germany. Of these there are about eight species, belonging to the genera Nothosaurus, Pistosaurus, Conchiosaurus, and Simosaurus, which have been described by Hermann von Meyer.

29. PTERODACTYLES, OR FLYING REPTILES.†—In this rapid sketch, it will not be necessary to dwell on the first appearance and subsequent great development of the Lacertian tribes through the periods embraced in this retrospective view, as we have already noticed at considerable length the principal extinct Saurians, whose remains have been disinterred from the secondary rocks. I pass, therefore, to the Pterosaurians, or Flying-lizards, of the ancient world, which unquestionably present the most extraordinary modification of reptilian organization which the researches of the palæontologist have brought to light. With a head and length of neck resembling those of a bird, the wings of a bat, and the body and tail of an ordinary mammal, these creatures present an anomaly of structure as unlike their fossil contemporaries as is the duck-billed Platypus or Ornithorhyncus of Australia to existing animals. The skull is small, with a long beak, furnished sometimes with upwards of sixty sharp-pointed teeth; the size of the orbit denotes a

* British Assoc. Reports for 1839, p. 126; and Monog. Cret. Rept. *1851*

† *Pterodactylus, i. e. Wing-finger.*—See Medals of Creation, p. 723.

large eye, and it is therefore probable that the smaller spe cies, like other Insectivora, were nocturnal. The outer or

LIGN. 137.—SKELETON OF A FLYING REPTILE: FROM SOLENHOFEN.

(Pterodactylus crassirostris, Goldfuss. One-third the natural size.)

From the Nova Acta Acad. Carol. Leop., vol. xv. pl. viii.

little finger is immensely elongated for the support of a membraneous expansion, similar to that which is extended on the fingers of the Bat; impressions of this membrane are seen in some specimens (*Lign.* 137). The fingers terminate in long hooks, like the curved claw of the Bat. The size and form of the foot, leg, and thigh show that the Pterodactyles were capable of perching on trees, and of standing firmly on the ground, where, with their wings folded, they might walk or hop like a bird.*

* *See Dr. Buckland's* Bridgewater Treatise. Mr. Martin has intro-

Twenty species of these extraordinary creatures have been discovered, varying in size from that of a Snipe to that of a Cormorant or an Albatross. Of these, twelve have been found in the lithographic stone of Bavaria,* where the bones of Pterodactyles are associated with the remains of Dragon-flies; in the Stonesfield Slate they are collocated with the *elytra*, or wing-cases, of beetles. In the Lias, the remains of a species of the size of a Raven were discovered by Miss Anning.† This species and three of those from Bavaria do not belong to the Pterodactyle proper; but, having no teeth, and being distinguished by their long stiff tail, they are separated by Von Meyer, under the name of *Ramphorhyncus* (Beak-nose).

Numerous thin delicate bones, evidently belonging to Pterodactyles, have been found in the Wealden, and prove that some species of these extraordinary creatures inhabited the country of the Iguanodon. In the Chalk of Kent, the upper and lower jaw-bones with teeth, portions of a coracoid bone, several digital bones, and parts of the arm-bones of large Pterodactyles, have been obtained. From a comparison of these relics with the specimen of *P. crassirostris* (*Lign.* 137), the Kentish species appear to have been much larger, and it is estimated that the expanded wings of *P. Cuvieri* would be, at least, eighteen feet wide; whilst in another Chalk species the extent of the wings from tip to tip was fifteen feet.‡ Among existing reptiles, the diminutive *Draco volans* is the only known species capable of flight.

duced a restored figure of a Pterodactyle in the foreground of the Frontispiece of Vol. I. of this work.

* Goldfuss, Nova Acta Acad. Nat. Cur. vol. xv. p. 63. This memoir, by the great German palæontologist, is illustrated by excellent figures of Pterodactyles from Solenhofen. See also Münster's "Beiträge."

† Geological Transactions, 2nd Ser., vol. iii. page 220. This unique specimen is now in the British Museum.

‡ The majority of the rare and valuable specimens from the Chalk, by

30. OPHIDIANS (*Serpents*) and BATRACHIANS (*Frog-tribe*).—There are no vestiges in the secondary formations of the Ophidians, or reptiles destitute of feet or any extremities for progressive motion; but in the tertiary, bones of a few species of large serpents, chiefly allied to the Boas and Pythons, have been discovered. These fossils were obtained from the Eocene sand, at Kyson, in Suffolk, from the London Clay of the Isle of Sheppey, and the Bracklesham beds on the Hampshire coast.* From the size of the vertebræ, Professor Owen ascertained that some of these Eocene serpents must have exceeded twenty feet in length. "Serpents of such dimensions," he observes, "exist in the present day only in warm or tropical regions; and their food is by no means restricted to animals of the cold-blooded classes. . . . Living birds or quadrupeds constitute the favourite food of the Pythons and Boas, of similar dimensions, which are exhibited in our menageries."†

A large fossil serpent, having some alliances with the Rattle-snake and other venomous Ophidians, has lately been described (under the name of *Laophis crotaloides*) by Prof. Owen,‡ from evidences afforded by several vertebræ collected near Thessalonica by Captain Spratt. It is probably of the Miocene age.

Batrachians.—The reptiles termed Batrachians (from the Greek name for Frog) are characterized by the remarkable metamorphoses which they undergo in the progress of their development from youth to maturity. Their organs of aerial respiration consist of a pair of lungs; but in their young and

means of which these gigantic Pterodactyles have been determined, enrich Mr. J. S. Bowerbank's choice collection at Highbury. See Owen's Monograph of the Chalk Reptiles, Palæont. Soc., 1851.

* Medals of Creation, p. 738.

† Geol. Trans. 2nd ser. vol. vi. p. 210.

‡ Geol. Journ. vol. xiii. p. 196, pl. 4.

aquatic state they are provided with gills, supported on cartilaginous arches, as in fishes. The early existence of colossal reptiles closely allied to this order has already been shown in the Labyrinthodons of the Triassic system (see p. 552). In the tertiary strata, the skeletons, imprints of the footsteps, and even vestiges of the soft parts of several species of Frog, Toad, and Newt, have been found.* In the *papierkohle* of the Browncoal of the Rhine (see p. 283), several species are met with.† In the neighbourhood of Bombay, small batracholites have been found in a black shale, apparently of tertiary date.‡

But the most celebrated fossil of this class, from the tertiary deposits, is a gigantic Salamander, three feet in length, obtained more than a century since, from the miocene lacustrine limestone of Œningen, in the same quarry which yielded the fossil Fox previously described (see p. 268). The first discovered specimen of this fossil Batrachian (*Lign.* 138) acquired great celebrity, from an eminent physician of his day, Scheuchzer, having, under some extraordinary delusion, regarded it as a petrified human skeleton, and described it, under the name of "*Homo Diluvii Testis et Theoscopos,*" as being "the moiety, or nearly so, of the skeleton of a man, with the bones and flesh incorporated in the stone, and a relic of that accursed race which was overwhelmed by the Deluge." §

Cuvier, when at Haarlem, in 1811, examined this specimen, and ascertained it to be the skeleton of an extinct species of aquatic Salamander; he cleared away the stone and exposed the four legs, and the jaws, beset with teeth.‖ There are

* See Pictet's Paléontologie, 2de edit. vol. i. p. 561.

† Goldfuss, Nova Acta, vol. xv. part 1, p. 107, pl. 11, 12, and 13.

‡ Geol. Journal, vol. iii. p. 224.

§ Philos. Trans. for 1726, vol. xxxiv.

‖ A full account and illustrations of this fossil are given in the "Ossemens Fossiles," vol. v. *p. 431* some fine remains of the Œningen Salamander in the collection of the British Museum.

Lign. 128.—Fossil Salamander of Œningen: Cryptobranchus Scheuchzeri.

("Homo Diluvii Testis" of Scheuchzer. Four and a half feet in length.)

31. Review of the age of Reptiles.—From the examination of the organic remains of the Secondary Formations we obtain the following results: that the seas, lakes, and rivers during these geological periods swarmed with reptiles, fishes, mollusca, crustacea, annelida, echinodermata, zoophytes, foraminifera, sponges, and sea-weeds; all of extinct species, and presenting, as a whole, a greater discrepancy with existing forms than those of the Tertiary; the most remarkable feature being the apparent absence of Cetacea (p. 325), and the presence of several genera of marine Reptiles.

On the land we find but little analogy to the terrestrial inhabitants belonging to the tertiary or present eras: throughout the vast accumulations of the spoils of the ancient Islands and Continents, although the remains of crocodiles, fresh-water turtles, insects, and terrestrial plants abound, a few jaws of very small animals are the sole indications of the existence of Mammalia; and the evidence of the presence of Birds is even less clear. In vain we seek for the relics of Man, or the remains of works of art,—for the skeletons of the Mastodon or the Mammoth,—of the Palæotheres, or other mammals that were their contemporaries; the osseous remains of terrestrial and fluviatile Reptiles alone appear. In the emphatic language of Cuvier, "*Nous remontons donc à un autre âge du monde,—à cet âge où la terre n'étoit encore parcourue que par des reptiles à sang froid, où la mer abondoit en ammonites, en bélemnites, en térébratules, en encrinites, et où tous ces genres, aujourd'hui d'une rareté prodigieuse, faisoient le fond de sa population.*"*

The earliest indications of air-breathing vertebrate animals is the little Elgin reptile, and the supposed imprints of chelonian footsteps in Devonian sandstone. In the succeeding Carboniferous, Permian, and Triassic periods, Saurobatrachians occur, often of great bulk, and in great numbers; and on the later sands of those old shores are found the foot-tracks of bipeds which seem to point to a higher class, that of birds, for their origin. In the following periods, embracing the deposition of the Lias, Oolite, Wealden, and Chalk, swarms of reptiles belonging to numerous genera everywhere prevail; species fitted to live in the air, on the land, in lakes and rivers, and in the seas,—yet not one identical with any existing form. These gradually decline as we approach the close of the secondary, and are succeeded in the tertiary by as varied modifications of the higher animals—the mammalia and birds. Thus, the faunas of the vast periods that intervened between the tertiary and palæozoic ages present the following numerical relations in the three higher classes of the vertebrata:—

MAMMALIA . .	Seven † genera of small land-animals (p. 394, 508, and 561). Wirtemberg, Stonesfield, and Purbeck.

* "Ossemens Fossiles," tome v. 2de partie, p. 10.

† Mr. Beckles has specimens of other Purbeck genera, still undescribed. The *Dromatherium* (Emmons), being probably Permian, is not reckoned here.

BIRDS	A species from North Carolina (p. 558, *note*); another from Stonesfield? (p. 524); another from the Wealden? (p. 452); and many species inferred from footprints on sandstone of the Triassic period? (p. 557).
REPTILES . . .	*Marine*;—Fifty genera, including above one hundred and forty species. *Terrestrial* and *Fluviatile*; — Forty-five genera, comprising about two hundred species. *Flying*;—Two genera, containing nineteen species.

Here, then, the classes Mammalia and Aves, which constitute the essential features of the existing terrestrial faunas of almost all countries, are represented through a period of time of incalculable duration, by a few diminutive quadrupeds, by some uncertain vestiges of birds, and problematical foot-prints of bipeds on the rocks; while everywhere bones, teeth, and entire skeletons of reptilian forms, adapted for aerial, terrestrial, and aquatic existence, afford unequivocal proofs that the air, the land, and the waters were tenanted by cold-blooded vertebrate animals. In the succeeding tertiary ages, the fossil remains of reptiles belong to species of existing types, and are associated with the relics of innumerable mammiferous quadrupeds.

Now, if we admit, to the utmost extent, the effect of causes that may be supposed to have operated to the exclusion of the remains of mammalia from the secondary formations, still the overwhelming preponderance of the reptilian tribes, both on the land and in the waters, is most striking. And here we may inquire whether this remarkable phenomenon warrants the hypothesis which some eminent geologists have advanced, namely, that during the periods antecedent to the eocene, the earth was not adapted for the existence of mammalia?—that it was in a state of turbulence and convulsion, which colossal reptile forms were alone calculated to endure; that it was a half-finished planet, unsuitable for warm-blooded animals; and that its atmosphere was incapable of supporting the higher types of animal organization? The probability that birds existed in the country of the Iguanodon—the certainty that marsupial and insectivorous mammals were the contemporaries of the Megalosaurus and Pterodactyles—that trees and plants, similar to many which now grow in regions abounding in birds and warm-blooded quadrupeds, flourished throughout the "Age of Reptiles," are facts which appear to me fatal to such a hypothesis, and to prove that the general temperature of the earth, and the physical constitution of the sea, and the atmosphere, were not essentially different from those which now prevail. That the class of reptiles was developed, throughout the periods embraced in this review, to an extent far beyond what has since taken place, cannot, I conceive, by any legitimate process of reasoning be disputed; but I do not think that in the present state of our knowledge any satisfactory explanation of this extraordinary fact can be offered.

32. Objections considered.—There are persons who, with one of the Bridgewater essayists (Mr. Kirby*), oppose these conclusions, and have recourse to the most strange conceits to account for the phenomena on which they are founded. But it is for those who refuse their assent to deductions made with the greatest caution, and derived from an overwhelming mass of evidence, to explain the entire absence of all traces, not only of Man, but of the whole existing species of animals and vegetables, in the ancient deposits; while there is not a river or stream which does not daily imbed the remains of the present inhabitants of the globe. But, however future discoveries may modify this hypothesis, they cannot invalidate the fact, that there is no country on the face of the earth with such an assemblage of animal life as that possessed by the regions whence the delta of the Wealden was derived; nowhere is there an island or a con-

* *Seventh Bridgewater* Treatise.

tinent inhabited by colossal reptiles only, or (excepting the Galapagos) where the Reptilia usurp the place of the large Mammalia. We have seen that this feature in the zoology of that remote period was not confined to the country of the Iguanodon; in every part of the world where geological researches have extended, this wonderful phenomenen appears —the absence of mammiferous animals in the older strata. The bones of reptiles, sometimes of enormous size, are there the only remains of the higher animals (except fishes) that occur in any considerable number. It is, therefore, manifest, that there was a period when oviparous quadrupeds of appalling magnitude were the chief possessors of the lands of which any traces remain in the strata that are accessible to human observation. I do not, however, mean to aver, that reptiles, and reptiles only, were the occupiers of every Island and Continent; but that it appears from the most irrefragable testimony, that the reptile tribes during the secondary periods were developed to an extent of which the present state of animated nature affords no example. It must be acknowledged that the proposition is astounding, and I do not feel any surprise that many intelligent persons, whose attention has not previously been directed to geological inquiries, should hesitate to admit its correctness; but the conclusion is drawn from such an immense accumulation of facts, corroborated by observations made in every region of the earth, as to compel assent, in spite of all our preconceived opinions. We may, indeed, call up from the depths of our ignorance hypotheses as marvellous as the phenomena they are intended to explain, but which a very slight examination of the facts before us would prove to be untenable.

33. CONCLUDING REMARKS.—There is another objection to which I would allude; for I do not think with some, that the errors or prejudices of those who differ from us should *be treated with* silence or contempt; but, rather, that it is

our duty to explain, again and again, the foundation of our belief, in the hope and assurance that we shall at length remove the erroneous opinions of persons whose scepticism arises from their imperfect acquaintance with the subject. It has been insisted upon by those whose views are limited to the present state of the globe, that the supposition of the earth having been peopled by other creatures before the existence of the human race is incompatible with the evident design of the Creator, and derogatory from the dignity of Man, for whose pleasure and necessities they assume all living things were created. But this inference is at variance with what we know of the living world around us: everywhere we see forms of animated existence utterly unconscious of the presence of Man, and endowed with faculties and sensations wholly dissimilar from our own. Thus, while in the beautiful language of Scripture we are told that not a sparrow falls to the ground without our heavenly Father's notice, a philosophical examination of the present constitution of nature would alike condemn such vanity and presumption. For my own part, feeling, as I do, the most profound reverence and the deepest gratitude to the Eternal Being, who has given unto me this reasoning intellect, however feeble it may be,—and believing that the gratification and delight experienced in the contemplation of the Wonders of Creation here are but a foretaste of that inexpressible felicity which, in a higher state of existence, will be our portion hereafter, I cannot but think that the minutest living atom, which the aided eye of man is able to explore, is designed for its own peculiar sphere of enjoyment, and is alike the object of His mercy and His care, as the most stupendous and exalted of His creatures.

"Le même Dieu créa la mousse et l' Univers."

In nothing, *perhaps,* are we more mistaken than in our *estimate of the* happiness enjoyed by other beings; to employ the beautiful simile of a distinguished author,—"As the moon plays upon the waves, and seems to our eyes to favour with a peculiar beam one long track amidst the waters, leaving the rest in comparative obscurity, yet all the while she is no niggard in her lustre; for, although the rays that meet not our eyes seem to us as though they were not, yet she, with an equal and unfavouring loveliness, mirrors herself on every wave; even so, perhaps, happiness falls with the same power and brightness over the whole expanse of being, although to our limited perceptions it seems only to rest on those billows from which the rays are reflected back upon our sight." * And if we admit, as all must admit who for one moment consider the marvels which Astronomy has unfolded to us, that there are countless worlds around us, inhabited by intelligences of whose nature we can form no just conception, surely the discoveries of Geology ought not to be rejected because they instruct us, that ere man was called into existence this planet was the object of the Almighty's care, and teeming with life and happiness.

Thus Geology reveals the sublime truth, that through periods of incalculable duration, our globe was the abode of myriads of living creatures, enjoying all the blessings of existence, and which at the same time were the destined instruments for the elaboration of the materials, by which the surface of the earth was rendered, in the course of innumerable ages, a fit temporary abode for intellectual and immortal beings! †

* Sir E. B. Lytton's "Eugene Aram."

† See M'Cosh and Dickie's "Typical Forms and Special Ends in Creation," 1856, for some interesting remarks on the adaptations of both fossil and recent animals and plants to their functions and conditions, and a brief notice of the evidences of a long preparation for the advent of man upon the earth (p. 345).

LECTURE VI.

ON ZOOPHYTA AND CRINOIDEA.

1. Introductory. 2. Organic and Inorganic Bodies. 3. Distinction between Animals and Vegetables. 4. Nervous System and Sensation. 5. Diversity of Animal Forms. 6. Zoophytes. 7. Animal nature of Zoophytes. 8. Cilia, or vibratile organs. 9. Hydræ, or Fresh-water Polypes. 10. Elementary organic structure. 11. Analogy not Identity. 12. The Bryozoa. 13. Food of Zoophytes. 14. Nature of Zoophytes. 15. Corals or Polypifera. 16. Sertularian Zoophytes. 17. Actinoidea or Corallaria. 18. Caryophyllia and Turbinolia. 19. Madrepore. 20. Fungia. 21. Astræa, Pavonia, &c. 22. Mæandrina cerebriformis. 23. Alcyonarian Zoophytes: Gorgonia. 24. The Red Coral. 25. Tubipora. 26. Geographical Distribution of Corals. 27. Appearance of living Corals. 28. Coral Reefs. 29. Coral Reef of Loo-Choo. 30. Coral Islands. 31. Formation of Coral Islands. 32. Montgomery on Coral Islands. 33. Fossil Zoophytes. 34. Ventriculites. 35. Zoophytes of the Oolite and Lias. 36. Corals of the Palæozoic Formations. 37. Coralline Marbles. 38. The Crinoidea. 39. Structure of the Crinoidea. 40. Encrinites and Pentacrinites. 41. Derbyshire Encrinital Marble. 42. The Lily-Encrinite. 43. Pear-Encrinite of Bradford. 44. Pentacrinites and Actinocrinites. 45. Pentremites and Cystidea. 46. Concluding Remarks.

1. Introductory.—In many of the deposits of the Secondary formations reviewed in the last discourse, a large proportion of the fossils were seen to consist of those interesting types of animal organization, the Polypifera and Crinoidea: some of the Oolitic strata, as for example the *Coral-rag*, being wholly made up of Corals; while many of the limestones and shales of the Lias equally abound in Pentacrinites and other forms of the Crinoidea. In the more ancient palæozoic formations, to the examination of which our attention will hereafter be directed, we shall find these organisms in still greater profusion: entire mountain-chains consisting of the consolidated remains of corals, and vast tracts of limestones composed of the mineralized skeletons of the Lily-shaped animals.

To enable the unscientific reader to comprehend the origin and formation of these ancient fossiliferous rocks, I therefore purpose devoting the present Lecture to a general view of the natural history of some of the recent animals of these classes, and a brief notice of the most characteristic fossil species.

2. ORGANIC AND INORGANIC BODIES.—The beautiful world in which we are placed is everywhere full of objects presenting innumerable varieties of form and structure, of action and position; some of them being inanimate or inorganic, and others possessing organization or vitality. The organic kingdom of nature, in like manner, is separated into two grand divisions, the animal and the vegetable. The differences between organic and inorganic bodies are numerous and manifest; but it will suffice for my present purpose to mention a few obvious and familiar characters.

All the parts of an inorganic body enjoy an independent existence; if I break off a crystal from this mass of calcareous spar, the specimen does not lose any of its properties, it is still a group of crystals as before: but if a branch be separated from a tree, or a limb from an animal, each is rendered imperfect, and the parts removed suffer decomposition,—the branch withers, and the limb undergoes putrefaction. If crystals, which may be considered the most perfect models of inorganic substances, be formed, they will remain unchanged, unless acted upon by some external force of a chemical or mechanical nature: within, every particle is at rest, nor do they possess the power to alter, increase, or diminish: they can enlarge by external additions only, and decrease but by the removal of portions of their mass.*

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* These remarks must be taken in a general sense only, since various experiments have demonstrated that the molecules of inorganic matter undergo modification by the slightest action of light and variation of temperature.

"Prismatic crystals of zinc are changed in a few seconds into octahedrons by the heat of the sun. We are led from the mobility of fluids to expect great changes in the relative positions of their molecules, which *must be in perpetual* motion even in the stillest water or calmest air; *but we were not* prepared to find motion to such an extent in the interior *of solids. We* knew that their particles were brought nearer by cold or

But organic bodies have characters of a totally different nature; they possess definite forms and structures, which are capable of resisting for a time the ordinary laws by which the changes of inorganic matter are regulated, while internally they are in constant mutation. From the first moment of the existence of the plant or animal to its dissolution there is no repose; youth follows infancy,—maturity precedes age; it is thus with the moss and the oak,—the monad and the elephant,—life and death are common to them all.

Animals and vegetables also require a supply of food and air, and a suitable temperature, for the continuance of their existence; and they are nourished by fluids elaborated by appropriate organs, and transmitted through suitable vessels. In the germ of an animal or a vegetable there is a vital principle in action, by which are developed in succession the ordained phenomena of its existence. By this power the germ is able to attract towards it particles of inanimate matter, and bestow on them an arrangement widely different from that which the laws of chemistry or mechanics could produce. The same power not only attracts these particles, and preserves them in their new situations, but is continually engaged in removing those which might by their presence prevent or derange its operations; and, on the other hand, so soon as the vital principle deserts the body which it has animated, the latter immediately becomes subjected to the agencies which act on inorganic matter: "in obedience to the power of gravitation the pliant twig hangs down, and the slender stem bends. In animals the body falls to the ground; the pressure of the upper parts flattens those on which the others rest; the skin stretches out; and the graceful rotundity of life is exchanged for the oblateness of death." * The laws of chemistry then begin to operate,—

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pressure, or removed farther from one another by heat; but it could not have been anticipated that their relative positions could be so entirely changed as to alter their mode of aggregation. It follows from the low temperature at which these changes are effected, that there is probably no portion of inorganic matter that is not in a state of relative motion. Prismatic crystals of sulphate of nickel exposed to the summer heat, in a close vessel, had their internal structure completely altered, so that when broken open they were composed internally of octahedrons, with square bases. The original aggregation of the internal particles had been dissolved, and a disposition given to arrange themselves in a crystalline form."—*Mrs. Somerville, On the Connexion of the Sciences*, p. 171.

* Dr. Fleming; Philosophy of Zoology, vol. i. p. 39.

putrefaction takes place,—and, finally, dust returns to dust, and the spirit of Man to Him who gave it.

3. Distinction between Animals and Vegetables. —I have thus briefly described a few of the phenomena peculiar to organic existence; it will now be necessary to offer some remarks on the distinguishing characters of animals and vegetables; for, unless we have a clear perception of the phenomena peculiar to each, we shall not obtain correct ideas of the nature of zoophytal organization.

When we compare together those animals and vegetables which are considered as occupying the highest stations in each kingdom, we perceive that they differ from each other in particulars so obvious and striking, as not to admit of question. The horse and the grass upon which it feeds—the bird and the tree in which it builds its nest—are so essentially distinct from each other, that we perceive at once that they belong to distinct classes of organic nature. But it is far otherwise when we descend to those animals and plants which occupy the lowest stations in vitality: here the functions to be performed are but few, the points of difference obscure, and it requires a correct knowledge of the laws of organization to enable us to determine, with any degree of precision, where animal life terminates, and vegetable existence begins. The Lichen which grows on the stone, and the Zoophyte attached to the rock, present but little difference to the common observer; both are permanently fixed to the spot on which they grow, from the earliest period of their existence to their dissolution; and in the vegetable dried by the heat of the sun, and the polype shrivelled up from the absence of moisture during the ebb of the tide, he would seek in vain for those characters which would assign the one to the vegetable, and the other to the animal kingdom.

4. Nervous System and Sensation.—My limits will

not permit me to dwell on the distinctions which exist between animals and vegetables in their chemical composition, nor on the different influence produced on the atmosphere by their respective agency: and I must content myself with explaining the remarkable endowment which is supposed to be peculiar to animal organization, namely, that of *sensation*, and to be dependent on that structure which is termed the Nervous or medullary system.

When any object comes in contact with my finger, I am sensible of its presence, and the finger is said to possess sensation: but if I compress or cut across the nerve which passes from the spinal marrow to the arm, this faculty of sensation is suspended or destroyed: the same object may come in contact with my finger as before, but no feeling is excited indicating to me its presence. This phenomenon is well known, for every one must sometimes, in lying or sitting, have compressed the nerve of the arm or thigh, and occasioned a temporary numbness and loss of accurate feeling in the limb. I perceive, then, by my own experience, that sensation is inseparably connected with the presence and condition of the nerves; and that in Man and the vertebrated animals the nervous influence is developed and transmitted by means of the brain, spinal chord, and nerves.

In examining the other divisions of the animal kingdom, the presence of a nervous system, more or less developed according to their respective intellectual and physical endowments, may be detected. In those of the higher orders, nervous filaments can be distinctly traced, from their origin in the brain or spinal marrow, to their distribution in the various parts to which they communicate sensation, and to the organs to which they impart the influence necessary for the performance of their several functions. But in proportion as the systems of absorbing, secreting, and circulating vessels become less, a corresponding diminution takes place in the nervous fibres, until at length both vessels and nerves elude our finite observation, and we are left to infer from analogy, that probably since sensation depends upon the presence of nerves, and the smallest animals evidently possess sensation, a nervous system exists in the minutest Monad which the highest power of the microscope enables us to descry.*

* Hence Rudolph, the celebrated physiologist, terms those animals in which no traces of *nervine*, or nervous matter, can be detected, the *Cryptoneura, or hidden-nerved.*

Our knowledge of the nervous system, even in the higher animals, is

In the largest and most complicated vegetable organisms no traces of nerves are perceptible, nor of any substance which can be considered as at all analogous in structure or function: it is therefore concluded, that, as vegetables are destitute of nerves, they are likewise wanting in the faculty we term sensation.*

But the nerves not only bestow feeling, they also confer the power of voluntary motion; and, if the organs to which the motor nerves proceed be suitably constructed, they enable the animal to effect progression, or, in other words, to change its situation from one place to another. As we descend in the scale of creation, we find many animals destitute of that power, and living on the same spot from the commencement to the termination of their existence; and all these creatures are inhabitants of the water.

Such, then, are the essential characters of animals—an external determinate form, gradually developed, with an in-

still imperfect; and "that there may be sensibility without nerves, and contractility without muscles," in the lower animals is a statement that has some support from observation. See "Seaside Studies," Blackwood's Magazine, 1857, p. 413, &c.

* Although the definition here given is sufficient for our present purpose, yet it is necessary to state, that, in a more rigorous and philosophical view of the subject, a line of demarcation between the vital phenomena exhibited by animal and vegetable organisms cannot be established. The possession of a stomach or digestive sac, and the power of locomotion, formerly thought to be peculiar to animals, are no longer regarded as such. Even the difference in the chemical processes effected by plants and animals,—namely, the absorption of carbonic acid and the evolution of oxygen by the former, and the opposite effects produced by the latter —though a very general, is not a constant character; for some animals evolve oxygen; and from all the parts of plants which are not green, carbonic acid is exhaled: and when light is removed from the plant, the same thing happens everywhere. See *Dr. Bence Jones's Gulstonian Lectures*, for 1846. The very difficult subject of the distinctive separation of the border-forms of animal and vegetable life is treated more or less fully in nearly every work, original or compiled, on zoology and physiology: for example, see Literary Gazette, 1856, p. 965; and Brit. and For. Med. Chir. Review, July, 1856, p. 3. The reader should also avail himself of the lucid and eloquent résumé of opinions on this subject in M. P. H. Gosse's elegant little work on "Life in its Lower, Intermediate, and Higher Forms," 1857, p. 25, &c., where Dr. Burnett (in *Siebold's "Comparative Anatomy"*) is especially quoted.

ternal organization possessing vessels for effecting nutrition and support, and capable of attracting and assimilating particles of inorganic matter; combined with a nervous system communicating sensation and voluntary motion; a certain term of existence being assigned to determinate forms,—in other words, a period of life and death.

5. Diversity of Animal forms.—Animals are as varied in form and magnitude as the imagination can conceive; from the god-like image of Man to the globule of jelly that floats upon the wave,—from the Elephant and the Whale to the Insect and the Animalcule, of which millions may be contained in a drop of water. In fact, so numerous and dissimilar, both in form and structure, are the animal organisms that exist on the earth, that the opinion of Astronomers that the inhabitants of the worlds around us must, from the different densities and conditions of the respective planets, be totally distinct and unlike any that are known to us, cannot be considered as incredible or marvellous.* But of all the shapes in which animal existence presents itself on our globe, none are more extraordinary, or unlike what is commonly conceived of living beings, than those of the compound creatures which have been described by naturalists under the name of "Zoophytes," or "Animal-plants," and are familiarly known in their varied forms by the names of Polyps, Corals, Dead-men's-hands, Sea-pens, Sea-fans, Sponges, &c.

6. Zoophytes.—In classifying the Animal Kingdom, naturalists have always readily recognised the distinctness of the three great divisions, now known as the Vertebrated (*Vertebrata* of Cuvier), the Molluscous (*Mollusca* of Cuvier), and the Articulate or Annulose animals (*Articulata* of Cuvier; *Annulosa* of Macleay); but besides these there is an extensive and somewhat heterogeneous series of ani-

* See *Thoughts on Animalcules, or a Glimpse of the Invisible World revealed by the Microscope, p. 7.*

mals, generally of far more simple structure as individuals, though frequently existing in compound and intimately united groups. These were termed *Radiaria* or *Radiata* by Lamarck, Fleming, and others, on account of the apparent or fancied radiation of the organs and parts of the animal. In this sub-kingdom were arranged the Echinoderms, the Zoophytes, the Entozoa, the Infusoria, the Sponges, &c. Recent researches have led to an improved classification of these lower animals in many respects, as may be seen in the works of modern anatomical and physiological naturalists;* and it will be sufficient here to point out that the word *Zoophyte* is now technically used to indicate the Corals only, although in a general sense all the plant-like animals are sometimes called Zoophytes.

Of these plant-like animals there are three important and very distinct groups. The *Bryozoa*,† or "Moss-animals;"

* See Owen's Lectures on the Invertebrate Animals, 2nd Edit.; Carpenter's General and Comparative Physiology, New Edit.; Huxley's Lectures on General Natural History in the "Medical Times," 1856–57; Van der Hœven's Hand-book of Zoology (translated by Dr. Clarke); Siebold's Hand-book of Invertebrate Animals; Milne Edwards' Zoologie; Dallas's Natural History of the Animal Kingdom; Rymer Jones's Animal Kingdom, New Edit.; Agassiz and Gould's Comparative Anatomy, &c., New Edit. (Bohn.)

† So called by Ehrenberg, on account of their small branches and frond-like forms, in contrast with the *Anthozoa*, or "Flower-animals," as he terms the true Corals, with the finely coloured flower-like expansions on their branching and often tree-like skeletons. Both of these groups have also other names; for instance, the *Bryozoa* or Moss-corals are the "Polyzoa" of Thompson, the "Zoophyta Ascidioida" of Johnston, and the "Ciliobrachiata" of Farre; and the Corals are the "Polypifera" of Grant, and the "Phytozoa" of Brandt.

The name *Bryozoa* is here preferred to the somewhat earlier one of "Polyzoa" (which Dr. Busk uses in his valuable descriptions of these little animals, in his "Catalogue of the Marine Polyzoa in the British Museum," and in his "Zoophytology" in the "Microscopical Journal"), because it is a better and more distinctive name, there being several other *groups of Polyzoic* animals; because it has been extensively used in the *Anthozoa*, or Corals (*Zoophyta* proper); and the *Amorphozoa*, or Sponges.

The Bryozoa* are compound animals, grouped on a horny or calcareous frame-work (termed the "polyzoary," or the "polypary," as is also that of the Corals, also the *cœnœcium*, or "common dwelling"); the individuals or polypes are of minute size; the body has a ring of hollow ciliated tentacles around the mouth; the alimentary canal consists of a stomach, gizzard, and an intestine, which has a free separate vent,—a character of much importance, placing the Bryozoa above the Corals in the scale of creation, and indicating their alliance, on the one hand, to the *Rotifera* among the Articulata, and to the *Brachiopoda* and *Tunicata* among the Molluscs, on the other. Many of the Moss-corals occur on the shells, rocks, and seaweeds of our shores; and some of them take the form of delicate Algæ, and have been often collected as such. They have been also miscalled "Corallines;" but the real Corallines (*Corallina officinalis* and its allies), although stony in structure, are really plants, belonging to the Algæ: there is, therefore, no relation, except that of "mimetic resemblance," between the Corallines and the Corals, much less the Bryozoa.

The *Anthozoa*, or *Polypifera*,† comprise three kinds of

zoology and palæontology; and because, in the case of appellations invented for groups of animals, plants, or minerals, whether they be names of genera, families, orders, or classes, it is not the priority, but the adaptability of the term that should, with few exceptions, determine the general use of such appellations, under which the many series of described species are successively grouped and regrouped by philosophical naturalists.

With "specific" names, however, the case is different; the published name of a species is (or ought to be) not only the established technical appellation of a distinct form in nature, but also the registered evidence of the successful labour and acumen of its discoverer and describer.

* *Medals of Creation*, vol. i. p. 265, &c.

† *Medals, vol. i. p.* 251, &c. See also Edwards and Haime's Mono-

Polyp-animals,—1st. one of very simple form of structure, like that of the "Fresh-water Polype," or *Hydra*; hence this group is called the *Hydroida*:* 2nd, with a less simple structure, other cavities existing in the body, besides that of the stomach; this is typified by the common Sea-anemone (*Actinia*); and the group is termed the *Actinoidea* or *Zoantharia* (animal-flowers), including the great mass of the stony Corals (Madrepores, &c.): and, 3rd, the *Asteroida* or *Alcyonaria*, having the common *Alcyonium* or Dead-man's-hand for their type, and being characterized by their nearly simple stomach, and by the polypary being either spongy or horny and gelatinous, and rarely forming a stony axis.

The Sponges, or *Porifera*,† present innumerable variations of form; they are composed of a usually fibrous skeleton, covered with a gelatinous coating, in which cilia and temporary alimentary openings have been observed;‡ the skeleton or axis is perforated with large and small passages, and is frequently interwoven with silicious or calcareous spicula. These creatures are much lower in the scale than either of the other Zoophytes. They hold a place on the confines of animality, and indeed present but few essential points of difference from vegetable organisms.

A group of fossil bodies, chiefly from the chalk, and known under the name of "Ventriculites," § were long regarded as Sponges; but, on account of certain peculiarities in the structure of their tissue, Mr. Toulmin Smith ‖ has assigned to them a higher place in the animal series.

graphs on Fossil Corals (Introduction), 1850—54, Palæont. Society; Dana's Zoophytes; Blainville's Actinologie, &c.

* Also known as the *Sertularidæ*. † Medals, vol. i. p. 219.

‡ Bowerbank, Report Brit. Assoc., 1856 and 1857; and Roy. Soc. Proc. 1857.

§ See above, vol. i. p. 330; and Medals, vol. i. p. 241. In the Linnæan Transact. vol. xi. p. 401, the author first referred these peculiar bodies to the *Alcyonium*.

‖ Ann. Nat. Hist. 2 ser. vol. i. 1848, p. 36, &c.

7. ANIMAL NATURE OF ZOOPHYTES.—Corals were long regarded by Naturalists as animal-plants (as the word "Zoophytes" literally means), but Ferrante Imperato, in 1599, and Peysonnel,* in 1751, were the first to insist on the true nature of these plant-like animals.† It was, however, in this town (Brighton) that, in the year 1752, the animal nature of many of the Zoophytes which abound on the Sussex coast was first established.‡ Mr. Ellis,§ an eminent Naturalist, was engaged in forming a collection of marine plants, and, having occasion to examine some of the specimens through a powerful microscope, he was astonished to find that the Sponges, at that time supposed to be vegetables, possessed a system of pores and vessels through which the sea-water circulated; and that many of the Bryozoa exhibited cells, from which tentacula or feelers were constantly protruding, and then suddenly retracting, as if seizing and devouring prey. Subsequent observations have proved that the substance we call "sponge" is the skeleton, or support, of a gelatinous and vascular, or sometimes granular, substance which invests it, and which may be considered as the flesh of the animal.‖ When viewed through the microscope, innumerable pores are seen on the surface of the Sponge constantly imbibing salt water, which circulates throughout the mass, and is finally rejected from the large openings; this water doubtless contains the living atoms that constitute the food of this zoophyte, but which are so minute as to

* Phil. Trans. Abridg. vol. x. p. 257.

† For the history of the researches of Naturalists among the Zoophytes, see Dana's "Structure and Classification of Zoophytes," 1846; Blainville "Manuel d'Actinologie," 1834; and Johnston's "History of British Zoophytes," 1838, and New Edit.

‡ See Prof. Allman's Introduction to his magnificent "Monograph of freshwater Polyzoa" (Ray Soc.), 1856, for a complete history of the recognition of these Zoophytes as animals, and as forming a distinct class.

§ Author of the beautiful work on "British Corallines," &c.— long the *standard authority on Zoophytology.*

‖ *Grant, Edinb. Phil.* Journ. vol. xiii. p. 102.

elude observation. It is only of late that, after long and patient observations, Mr. Bowerbank has succeeded in demonstrating the existence of true mouth-like openings in the jelly-like coating, or sarcode, of the Sponge. These, however,—wonderful as it may appear!—are of a temporary nature; being opened in any part of the surface, apparently at the will of the animal, and at long intervals of time, and closing up again in a short time, without the least trace of them remaining.*

The Sponges, however, approach so closely in their structure to certain plants, that many eminent Naturalists have referred them to the Vegetable kingdom, believing that, if a line could be drawn between animals and vegetables, the Sponges should be placed among the latter. But these bodies appear to me to hold an intermediate place,—to be on the boundary line that intervenes between the two grand divisions of animated nature; they are, in short, true Zoophytes or Animal-plants; it will, therefore, be instructive to dwell a brief space on the investigation of their structure and economy.

The living Sponge, when highly magnified, exhibits a cellular tissue, permeated by pores, which unite into cells, or tubes, that ramify through the mass in every direction, and terminate in larger openings. In most Sponges the tissue is strengthened and supported by spines or spicula of various forms, and which, in some species, are silicious, and in others calcareous.† The minute pores through which the water is imbibed have a fine transverse gelatinous net-work, and projecting spicula, by which large animalcules or noxious particles are excluded; water incessantly enters into these

* Bowerbank, Brit. Assoc. Reports, 1856, p. 438; and 1857.

† For descriptions of the Spicula of Sponges, see Prof. Quekett's Lectures on Histology; and his Catalogue of the Histological series in the Museum of the College of Surgeons, p. 177, &c., pl. 10, 11. Mr. Bowerbank's forthcoming History of the British Sponges (Ray Society) will *supply full details* of all these curious organic structures.

pores, traverses the cells or tubes, and is finally ejected from the large vents. But the pores of the sponge have not the power of contracting and expanding, as Ellis supposed; the water is attracted to these openings by the action of instruments of a very extraordinary nature (cilia), by which currents are produced in the fluid, and propelled in the direction required by the economy of the animal.*

8. CILIA,† OR VIBRATILE ORGANS.—Although these organs, which are termed *Cilia* from their hair-like appearance, are not confined to the class of animals which form the subject of this inquiry, yet they play so important a part in the economy of Zoophytes and all other animals, that it will be necessary to define their structure and functions. These processes resemble very slender fibres or hairs, and are only visible under a powerful microscope. They are situated on parts habitually in contact with water or some other fluid, and possess the power of performing a rotatory or circular oscillation with great rapidity, by which they produce currents and eddies in the surrounding fluid.

When a drop of water containing Infusoria is brought under the microscope, it is seen that, as the creatures move along, every particle of foreign matter near them is agitated, a phenomenon indicating eddies in the water. When the animalcules remain stationary, the currents are more distinct, and evidently take certain directions, causing the particles of matter to run in a stream to and from the animal. If a very high magnifying power be employed, transparent filaments will be distinguished projecting from the surface of the animalcules, and moving with extreme rapidity. These are the Cilia, which serve to assist in progression, and when the animal is stationary, impel the water in currents through the cavities and tubes on which they are distributed: these must not be mistaken for the tentacula, or feelers, for they are fringes of delicate fibres investing those instruments and the internal surfaces of other organs. The Cilia are so minute, that their outward form, position, and the direction of their motions only can be detected, their internal struc-

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* Dr. Grant, Mr. Bowerbank, and some other Naturalists affirm the existence *of vibratile cilia in Sponges*. See Gosse's "Life," p. 4, and p. 34, &c.

† From *cilium*, an eye-lash.

ture eluding observation. In the simplest animal organisms they are the organs by which motion and respiration are effected, and the food necessary for nutrition obtained. But they exist also in Man and the higher orders of vertebrata, and are the instruments by which many of the most important functions of the animal economy are performed. As we cannot separate the idea of muscular fibre from animal motion, it is conjectured that the Cilia are impelled by definitely arranged muscles: and Ehrenberg believes he has detected these muscles in some of the larger Infusoria.* The number of the cilia, even in an animalcule invisible to the naked eye, is almost incredible; Dr. Grant calculates that a single polype of a Flustra has 400 millions.

9. THE HYDRA, OR FRESH-WATER POLYPE.†—Before describing the zoophytes which are the immediate subject of this Lecture, I would call your attention to one of the most simple forms of animal life that abounds everywhere in fresh-water streams, and, being relatively of considerable size, will afford a convenient illustration of some of the vital phenomena exhibited in the coral-zoophytes which give rise to reefs and islands in the seas of warm climates, and of one group of which (the *Hydroida* or *Sertularidæ*) it is the simplest form and type. This is the *Hydra*, or fresh-water polype, of which two or three kinds inhabit our ponds, rivulets, &c. They are generally attached to the stems and leaves of aquatic plants; and the largest species, when in an expanded state, is from a quarter to half an inch long, and of the size of a hog's bristle; it is constricted at the end attached to the plant, and has an aperture or mouth at the free extremity, from around which proceed from six to ten

* See the representation of the Cilia on the rotatory organs of the Rotifer or Wheel-animalcule in "Thoughts on Animalcules," p. 35. The continuance of the ciliary motion in parts separated from the rest of the body of *Mytilus* and many other animals, and even for some time after death, proves that the action is automatic, or independent of the will of the animal.

† Polype, or polypus (*many feet*), is a name derived from the tentacula or processes which in some species serve for progression, in others for respiration. The name has been also applied to some of the many-
Cephalopods.

long delicate tentacula (*Lign.* 139, *fig.* 4). The *Hydræ* present an example of a highly endowed organism of the simplest structure; the whole animal consisting merely of a gelatinous, transparent, open cylinder, or tube, contracted at one extremity, and having the margin of the other prolonged into tubular tentacula. It is, in fact, a stomach, or digestive sac, with no a pendage but the instruments for

LIGN. 139.—HYDRÆ OR FRESHWATER POLYPES.

(The type of the Hydroid or Sertularian Corals.)

Fig. 1. *Hydra fusca* magnified, the tentacula partially expanded. 2. Two Hydræ on the same base, one contracted, the other expanded. 3. *Hydra viridis*, natural size. 4. Hydra, with the body enlarged from its containing food. 5. Vertical section of *Hydra viridis*, highly magnified. 6, 7, 8. Hydræ in various states of progression. 9. A double Hydra, produced by the vertical section of a single one.

seizing its prey. A vertical section (*Lign.* 139, *fig.* 5), highly magnified, shows the interior of the receptacle for the food, the relative thickness of its substance, and the manner in which the tentacula are formed by an extension of the upper margin. The Hydra is endowed with vitality in a very extraordinary degree, and its substance is highly sensitive and contractile in all its parts. It fixes itself to other bodies by the small end of the tube, and expands and contracts at pleasure. These enlarged drawings (*Lign.* 139) represent the polypes in different positions and states of contraction. The mode of progression is shown in *figs.* 6, 7, 8; it is effected by the bending of the body into a curve, and holding by the tentacula; the base is then brought into contact with the fixed point, and the tentacula are again projected forwards. The Hydra * can greatly elongate the body, and also contract itself into a small globular mass, as in the uppermost polype in *fig.* 2.

The most extraordinary vital endowment possessed by these fresh-water polypes is that of the reproduction of lost parts to an almost unlimited extent; even to the formation of several perfect animals from the separated pieces of a single individual. If the body be split in half, each portion grows into a complete Hydra, as is shown in this drawing (*fig.* 9); and, as if there were no limits to its transformations, the creature may be turned inside out, and that which was the surface of the stomach will become the epidermis, and the outer skin form the lining of the new stomach, and carry on the process of digestion! †

10. Elementary organic structure; Cells.—The interpretation of these phenomena is to be found in the peculiar organization of the Hydra, its entire structure being nothing more than an aggregation of cells.

A vertical section of the Polype (*Lign.* 139, *fig.* 5) shows the internal cavity or digestive sac, the relative thickness of the substance of the body, and the manner in which the arms are formed by a prolongation of the upper part into hollow processes. This animal is, in fact, a simple sac or pouch formed of a congeries of cells, for the reception and assimilation

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* See "Thoughts on Animalcules," Pl. I., for coloured figures of the Hydræ.

† Abraham Trembley of Geneva, in 1740, first observed this wonderful property of the Hydra. See his work, "Mémoires pour servir à ...e d'un Genre de Polypes d'Eau douce." 4°. Leyde, 1744.

of food. The cells lining the stomach select and absorb the nutritious particles, and the tube then spontaneously contracts and casts out the residue of digestion. This organization is analogous to that of the simplest condition of the vegetable kingdom, the *Cellulosæ:* for even the large *Fuci*, or sea-weeds, consist only of cells. The fresh-water *Confervæ* are merely jointed films composed of cells, containing granules or lesser cells. A cell bursts, the granules escape, and float in the water until they become fixed to some other body; they then reproduce cells, which are aggregated after the same pattern as in the parent plant. The common mould or mustiness is a cluster of plants formed of cells only; and there are some vegetables in which the entire plant consists of but *one isolated cell;* such as the red snow (*Leparia nivalis*); whilst in the yeast-fungus (*Tortula cerevisiæ*), the plant consists of but one, two, three, or a few more. In these examples we see that all the functions of vegetable life, namely, absorption, assimilation, the fixation of carbon from the atmosphere, respiration, exhalation, secretion, and reproduction, can be effected by one single cell. Even in the highest and most complicated orders of vegetables, in which there is a variety of organs adapted for the performance of different offices, these functions are effected by the agency of cells, which obtain materials of formation and support from the ordinary chemical agents around them. Thus an aggregation of simple cells forms the cellular tissue; a fusion or blending of several cells produces the vessels, and so forth; and by cells are elaborated the gum, resin, oil, starch, gluten, &c.: and by cells specially endowed are secreted the narcotic substance of the poppy, the deadly poison of the nightshade, and the stimulant aromatic of the clove.

In like manner, in animal structures, all the various processes of vitality are performed by cells or globules, varying in size from infinite minuteness to forms visible to the unassisted eye. Thus one system of cells secretes the bile, another the adipose substance, another the nervous matter, and so forth; but how these special products are formed by cells apparently of similar organization we know not. Whether the special endowment belonging to the system of cells of a particular organ depends on the intimate structure of the wall or tissue of such cells, and this structure be so attenuated and infinitesimal as to elude our observation,—or whether it results from the transmission of some peculiar modification of that mysterious vital force we term nervous influence,—are questions to which, I apprehend, no satisfactory reply can be given.

In fine, a minute globular cell is typical of the common germ from which all organic fabrics proceed. All animals and plants, therefore, may justly be *regarded as definite* aggregations of cells, endowed with *specific properties in the different* types, and subjected to a never varying law of development; and in animals, as well as in plants, there are certain kinds in which the entire organism consists of but a single cell;* and others in which each individual is but a cluster of such cells arranged in a definite manner. These mere aggregations of cells perform all the functions of animal life, viz. the maintenance of a particular form for a certain period, the elaboration of materials of support from food, locomotion, and the perpetuation of the species; hence these animals, like the analogous plants, may be divided without losing their vitality, and every part become a perfect individual. To this class of organization belongs the Hydra; and the above exposition of its structure renders the production of several animals from the vivisection of an individual perfectly intelligible.

11. ANALOGY NOT IDENTITY.—And here I must briefly comment on the doctrine of the *law of development*, as it is termed, so speciously, but unphilosophically, advocated in a late work,† in which it is attempted to show, that all the varied forms of organic life are the result of a law by which is produced an unbroken chain of gradually exalted organization, from the crystal to the globule, and thence through successive stages of the polype, mollusk, &c., up to Man.‡

The following remarks will serve to show the fallacy of this reasoning. Though it is an established physiological axiom, that cells are the elementary basis, the ultimate limit to which we can trace all animal and vegetable structures, and that the varied functions in which organic life essentially consists are performed by the agency of cells not distinguishable from each other by any well-marked characters, there is not the slightest ground for assuming any identity between the primary cells of the simplest species of animals and vegetables, much less those of higher

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* The Monads: see "Thoughts on Animalcules," Plate II.

† Vestiges of the Natural History of the Creation.

‡ The following remarks of Sir John Herschel on this theory are too important to be omitted. "The transition from an inanimate crystal to a globule capable of such endless organic and intellectual development is as great a step—as unexplained a phenomenon—as unintelligible to us—and in any human sense of the word as *miraculous*, as would be the immediate creation and introduction upon earth of every species and every individual. Take the amazing facts of Geology which way we will, we [illegible]sort elsewhere than to a mere speculative law of development for [illegible]nation."—*Brit. Assoc.* Report for 1845, p. 42.

organization. The single cell which embodies vitality in the yeast-fungus or the monad is governed by the same immutable organic laws which preside over the complicated structure of Man and the other vertebrata: and the single cell which is the *embryotic* condition of the Mammal has no more relation to the single cell which is the *permanent* condition of the monad, than has the perfect animal into which the mammalian cell is ultimately developed. The cell that forms the germ of each species of organism is endowed with special properties, which can result in nothing but the fabrication of that particular species. There is an *analogy* between the human embryo and the monad of the Volvox, in that each consists of simple cells; but there is no more *identity* between the human and infusorial cells than between the perfect Man and the mature Animalcule.*

12. The Bryozoa.—From this digression we return to the consideration of the Zoophytes, and especially of the *Bryozoa*, which stand first in order among the plant-like animals, and are well called Moss-animals on account of their aggregated masses incrusting other bodies like moss. They present numerous fresh-water species,† as well as an extraordinary abundance of marine forms. Their polypes, though exceedingly minute, are highly organized, their digestive organs being more complicated than those of the other tribes of Zoophytes.‡ I will select one of the most simple and common forms in illustration of the subject. Most persons in their rambles along the sea-shore must have noticed on the seaweeds, shells, and pebbles patches of a white reticulated substance, which, when closely examined, appear like delicate lace-work: these, apparently mere earthly particles, are clusters of the compound zoophytes termed *Flustra*§ or "Sea-mat." (*See Plate* V. *figs.* 5, 6, 7, 8.)

* See Notes to "Thoughts on Animalcules;" and Westminster Review, No. XC. Art. "The Microscope and its Revelations."

† Most philosophically described and most beautifully illustrated by Prof. Allman in his "Monog. Fresh-water Polyzoa," 1856 (Ray Society).

‡ See above, p. 601.

§ The word *Flustra* is here intended to comprise the closely-allied genus *Membranipora*, as formerly, for the sake of convenience of reference and description.

[illegible] was seen to be covered with a [illegible] of [illegible] substance, [illegible] the hard frame-work was secreted. [illegible] the form and structure of the [illegible] may be easily distinguished. Pl. V. fig. [illegible] with its tentacula extended: [illegible] fig. [illegible] withdrawn into its cell. The [illegible] fig. [illegible] a polype protruded under a much [illegible] †

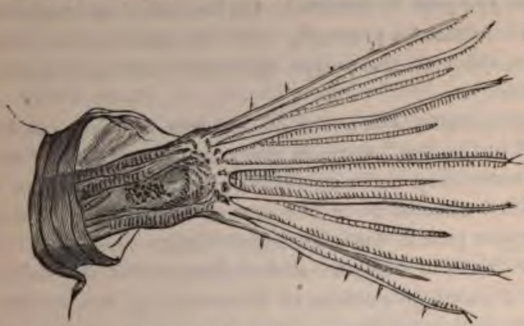
[illegible] of the animalcule consists of a transparent sac [illegible] on itself, and having at the mouth, or [illegible] opening, ten or twelve tentacula fringed with [illegible], which have the power of extending and contracting [illegible] with great celerity.

The [illegible] Bryozoa present considerable variety in the

* [illegible] technical descriptions, and detailed illustrations of the [illegible] and their allies, see Johnston's *Brit. Zoophytes*, 2nd Edit. p. [illegible]; [illegible] *Polyzoa Brit. Mus.* p. 46; and Alder's *Cat. Zoophyt.* p. [illegible].

† This figure is from a memoir by Mr. Lister (Philos. Trans. 1834) [illegible] and functions of the Tubular and Cellular Polypes. The [illegible] made at Brighton, and I had the pleasure of seeing the [illegible] under the fine instrument constructed by Mr. Lister.

form and arrangement of their cells. Some of the most common species are found attached to marine plants, which they enclose, as it were, in a living sepulchre (*Pl.* V. *fig.* 5); others spread into foliated expansions, and have both sides covered with cells. The prevailing hue is white, or a light-fawn colour, but some species have a tinge of pink or



LIGN. 140.—POLYPE OF FLUSTRA* PILOSA; WITH ITS MOUTH AND CILIATED ARMS PROTRUDED FROM THE CELL.

(Magnified 150 times.)

yellow. Numerous species† resemble in miniature the branching tree-like forms of the Corals, or other coralloid and spongoid shapes. They abound in every sea, are not restricted by climate, occur in profusion along the sea-shores, and are found attached to the fuci that are thrown up from below low-water mark.‡ The small parasitical species, when dried, appear like spots of a chalky substance on the sea-weed.

* *Membranipora*, Busk, Polyz. Brit. Mus., p. 56, pl. 71.

† Medals, p. 268, *fig.* 89.

‡ A concise notice of the distribution of Molluscous animals in the several "zones" into which naturalists have divided the bed of the sea, will be found in Woodward's "Manual of the Mollusca," p. 439: and in Mr. J. Alder's "Catalogue of the Zoophytes of Northumberland and Durham" (Trans. Tyneside Nat. Field Club, vol. iii. p. 98), the reader will find upwards of 200 species of British Anthozoa and Bryozoa arranged according to their *distribution into zones* of depth.

The increase of the Flustra is thus described by Lamouroux. —When the animal has acquired its full growth, it flings from the opening of its cell a small globular body, which fixes near the aperture, increases in size, and soon assumes the form of a new cell; it is yet closed, but through the transparent membrane that covers its surface the motions of the polype may be detected; the habitation at length bursts, and the tentacula protrude, eddies are produced in the water, and conduct to the polype the atoms necessary for its subsistence.

Innumerable specimens of Bryozoa or Moss-corals* are found in the fossil state, in every geological formation; and sometimes they occur in such abundance as to form whole stratified masses, as in the case of the Suffolk Crag,† and the upper part of the Maestricht Chalk. The White Chalk of the South of England, and of France and Germany, contains a large proportion of Moss-corals,‡ but chiefly in a fragmentary condition.

The *Graptolites*,§ found in the Silurian rocks, have been referred by some authors to the Bryozoan group; by others, however, they have been placed with the *Virgulariæ* of the Alcyonarian order.

13. THE FOOD OF ZOOPHYTES.—However improbable it may appear to the mind unaccustomed to investigations of this nature, that beings so minute as those under examination should prey upon living forms yet more infinitesimal, the fact is nevertheless unquestionable. It is even possible to select the food of animalcules much smaller than the

* Medals, p. 265. From the imitative resemblance of many of their little polyparies to those of the larger Corals, the Bryozoa are often referred to by the above name.

† This was formerly termed "Coralline Crag," owing to the then imperfect state of the nomenclature of the Zoophytes. See vol. i. p. 224.

‡ See vol. i. p. 331. Also D'Orbigny's "Paléontol. Française;" and Hagenow's "Die Bryozoen der Maastrichter Kreidebildung."

§ *Medals, p. 255.*

polypes of the Flustra, and thus exhibit their internal structure. This experiment is easily shown under a good microscope, and the animalcules termed *Vorticellæ*, a very abundant family of Infusoria, are best adapted for the purpose. Immediately on a minute particle of a very attenuated solution of pure carmine or indigo being applied to a drop of water containing a group of the *Vorticellæ*,* the most beautiful phenomena are observable. Currents are excited in the fluid in all directions by the rapid motion of the cilia, which form a crown round the anterior part of the body of the animalcules, and the particles of indigo are seen moving in different directions, but generally all converging towards the orifice or mouth, which is situated not in the centre of the crown of cilia, but between the two rows of these organs, which exist consecutive to one another. The attention is no sooner drawn to this interesting spectacle, than presently the bodies of the animals, which were before quite transparent, become dotted with distinctly circumscribed spots, of a dark-blue colour, exactly corresponding to that of the moving particles of indigo. In some species, particularly in those which are provided with an annular contraction or neck, separating the head from the body, the molecules of indigo can be traced in a continuous line in their progress from the mouth to the internal cavities.

The animalcules termed *Monads* may be considered as the lowest term of animal organization recognisable by man, being only from the 1,200th to the 24,000th part of an inch in diameter, and the powers of the microscope extend no farther; yet it is impossible to doubt that there are myriads of living forms more infinitesimal, some of which serve as food to these miniatures of life.†

* The Vorticellæ are hyaline vase-shaped or bell-like animalcules, attached by a slender peduncle at the base, and having rows of cilia disposed in zones round the margin; these, when seen in some directions while in rapid motion, appear like wheels. See "Thoughts on Animalcules," Pl. III.

† "The size of the *ultimate particles* of matter must be small in the

14. Nature of Zoophytes.—In the larger and free masses of Flustra, the decomposition of the animal substance after death is very manifest. This specimen of *Flustra foliacea*, which was dredged up twenty miles SSW. of Brighton, in water eighteen fathoms deep, is a fine example of this brittle species; when first in my possession it was highly offensive from the emanations evolved during the decomposition of the animal matter. It is now a flexible calcareous skeleton, with here and there portions of the shrivelled integument, but, of course, without any traces of polypes in the cells.

Let us now refer to our previous remarks, and inquire if the Flustra presents the essential characters of animal existence. Its polype possesses a determinate form, and has a calcareous skeleton covered by a soft fleshy substance, that can for a certain period resist chemical and mechanical agency. It is furnished with instruments capable of moving with great celerity, is susceptible of external impressions, and can expand and contract at will. Here, then, is evidence of sensation and of voluntary motion; and although, from the extreme minuteness of the structure, nerves cannot be detected, yet there can be little doubt that it possesses a nervous and also a circulatory system for effecting nutrition and reparation. We find, also, that, when removed from the element in which it lived, the creature dies, and its soft substance, like the flesh of the larger animals, undergoes putrefaction; it has lost the vital principle by which it previously resisted chemical agency, and now submits to the effects of those laws which act upon inorganic matter; the

extreme. Organized beings, possessing life and all its functions, have been discovered so small that a million of them would occupy less space than a grain of sand. The malleability of gold, the perfume of musk, the odour of flowers, and many other instances might be given of the excessive minuteness of the atoms of matter: yet, from a variety of circumstances, it may be inferred that matter is not infinitely divisible."—*Mrs. Somerville*, p. 125.

calcareous and horny materials that composed its skeleton, and which, like the bones of mammiferous animals, were secreted by the soft parts, alone remain.

I would here particularly remark, that the stony support of all Zoophytes is formed by a similar process; the hard substance called *coral* being secreted by the integuments or membranes with which it was permeated and invested, in like manner as the bones and nails in man are secreted by the tissues designed for that purpose, and acting without his knowledge or control. Nothing can be more erroneous than the popular notion that the cells of corals are built up by the polypes found in them in the same manner as are the cells of wax by the Bee.

From what has been advanced, it is evident that the Flustra is an aggregation of an immense number of individual polypes attached to a calcareous or horny skeleton, and each of which is doubtlessly susceptible of pain and pleasure independently of the whole; for we have a living proof in the Siamese twins,* that even in our own species there may be a united organization with separate nervous systems, and individual sensations; and, as it is certain that each polype enjoys distinct volition, it is most probable that the sensations of each individual are independent of the general mass. There is, however, a common sensibility pervading the structure that binds together the community of zoophytes, and by which certain actions are performed irrespectively of the individual polypes. Thus the compound zoophytes termed *Pennatulæ*, or Sea-pens,† upon the slightest touc withdraw themselves into the wet sand, and disappear: and the arborescent *Vorticellæ*,‡ upon the microscope being agitated, instantly shrink down into a globular mass, and all appearance of the elegant animalcules, a mo-

* See the Philosophical Transactions for 1830, p. 177.

† Belonging to the *Alcyonaria*.

‡ See "Thoughts on Animalcules," p. 49.

ment before so active, vanishes. In certain species of Bryozoa (*Bugula flabellata*,* for example), each cell is accompanied by a bivalved appendage, much resembling in form the beaks and head of a vulture, and termed the "avicularium;" and these appendages open and shut apparently without the control of the polype that occupies the cell; their functions seem to be related to the horny axis that connects the group of independent living animalcules of which the entire compound zoophyte is composed, and not to the polypes themselves.†

15. THE CORALS, OR POLYPIFERA.—The Corals, or *Polypifera* (Zoophytes proper), present an extensive series of varied and extraordinary forms of zoophytal organization. In some, the skeleton‡ or support consists of various combinations of earthy and animal matter, as it is in the Flustra, but solid and hard as stone; in many examples it branches out like a tree (*Lign.* 143, p. 624); in others, it constitutes hemispherical masses, having numerous convolutions on the surface, somewhat resembling in appearance the brains of quadrupeds (*Lign.* 144); and in many it forms an aggregation of tubes, terminating in star-like openings (Pl. VI. *fig.*

* Formerly known as *Flustra avicularis*. See Busk, *op. cit.* p. 44, pl. 51, 52.

† The reader will find some highly interesting observations on this phenomenon in Mr. Darwin's "Journal of a Voyage round the World," chap. ix. p. 200. Mr. Gosse has suggested that possibly the use of the *avicularia* may be to fortuitously catch and to hold minute animals until, attracted by their decomposition, hosts of other animalcules swarm in the neighbourhood and come within the currents produced by the ciliated tentacles of the zoophytes themselves.

‡ The axis, framework, or skeleton of these groups of polypes is termed *polypary*, or *polypidom* (polype-habitation); and those of a stony hardness are familiarly known as "Coral:" these names therefore refer to the durable skeleton of the zoophytes, and not to the polypes themselves; but in familiar writing the term Coral is often used to designate *the entire living mass*. In a fossil state the polyparium alone remains, *except in a few instances*. See "Medals of Creation," chap. vii.

9). Among the branched varieties, some are covered by pores so numerous as to be called *Millepora:* in many, the openings are distant: some have star-like markings here and there; while in others, the whole surface presents a stellated structure. In many species the fleshy animal matter entirely covers and conceals the stony skeleton during life; in others, the latter becomes exposed, and forms a trunk, having branches covered by living polypes; while in another and numerous division (of which the common *Sertularia* is an example), the skeleton is flexible, and is secreted by the outer surface of the soft parts, and constitutes an external protection to the polypes (*Pl.* V. *fig.* 1). In another family, the *Gorgonidæ* (*Lign.* 145), the skeleton is of a horny or ligneous texture, and flexible, bending to the motions of the waves; while in some it is jointed or articulated, as in the *Isis* (*Lign.* 143, *fig.* 3). Sometimes the skeleton is impressed with the cells, as in the Madrepores (*Lign.* 143, *fig.* 2); while in other species, as the Red Coral, the stem is smooth, and exhibits no traces of the peculiar structure of the animal, the polype-cells being formed of the investing soft substance (*Pl.* V. *fig.* 9). Yet amidst all these varieties of form, the same essential characters are maintained; in all there is a skeleton or solid support, and a fleshy or gelatinous substance, either investing the polypidom and studded with polypes having more or less simple stomachal cavities; or constituting separate polypes, but more or less intimately connected by imtermediate animal and calcareous matter.

16. THE SERTULARIAN ZOOPHYTES.* — The *Hydra*, as above mentioned, p. 606, is regarded as the type of the Sertularian Zoophytes; † and, supposing it to be invested with a

* For the classification and description of the members of this group, the reader is referred to Johnston's "British Zoophytes," 2nd Edit.

† There have been of late years discovered some remarkable points of alliance between these Hydroid zoophytes and the Acalephs (Medusæ, &c.).

horny coat, to be elongated by growth, and to retain all the buds, or young Hydræ, which are formed on its axis or stem throughout life, we might regard it as truly analogous to a *Sertularia*. The elegant arborescent *Sertulariæ* must be familiar to every one who has rambled by the sea-side. This branch of the Sea-pine (*Lign.* 141), part of which is shown magnified in *fig.* 2, exhibits the usual appearance of these zoophytes. The Sertularia consists of tubes united together, and having lateral apertures for the protrusion of each polype; one elegant species, the *Sertularia setacea*, is very

1 2

LIGN. 141.—SERTULARIA NIGRA (JOHNSTON).

Fig. 1. Natural size. 2. A portion highly magnified (the tentacles not being protruded from the cells).

abundant on the shores at Brighton after storms, being attached to fuci and other sea-weeds. The representation of a branch, magnified sixty times, in *Plate* V. *fig.* 1, shows the form of the polypes, which, when fully expanded, are of great beauty. On one occasion, when I was present, Mr. Lister was observing a living specimen, when a little globular animalcule swam rapidly by one of the expanded polypes; the latter immediately contracted, seized the globule, and brought it to the mouth or central opening by its tentacula;

these gradually opened again, with the exception of one which remained folded, with its extremity on the animalcule. The mouth indistinctly seemed filled with hairs or tentacles, that closed over the prey, which, after a few seconds, was carried slowly down into the stomach; here it was imperfectly seen, and soon disappeared.*

The *Campanulariæ*, so named from their *bell-shaped* cells placed on foot-stalks, also belong to the Hydroid polypes, and are abundant on our shores. *Pl.* V. *fig.* 2, is a magnified view of a branch of *Campanularia gelatinosa*, with several cells; in some the polypes are expanded, in others contracted. Examined alive under the microscope, currents of minute globules are seen constantly running along the tubes, induced by the action of the invisible cilia.

17. THE ACTINOIDEA, OR CORALLARIA.†—Having described some of the principal characters of the Hydroid or Hydrarian Polypifers, the lower group, in which digestion is performed by a simple sac or pouch, as in the common *Hydra*,‡ we proceed to indicate the leading forms of the two other great groups§ (the Helianthoid or Zoantharian Corals, and the Alcyonarian group), with some remarks on their nature and habits. In the Corals proper, the framework or polypary is generally calcareous; the species of the soft-bodied Zoantharia (or Actinidæ) being of a limited number; whilst the stony or "coralligenous" Zoantharia have very numerous species, both in the fossil and the re-

* Philos. Trans. 1834, p. 372.

† Milne Edwards and Haime, Monog. Brit. Foss. Corals (Palæont. Soc.), 1850, p. ix.

‡ See Owen's Lectures on the Invertebrata. Of the many notices and monographs of the *Hydra*, Corda's memoir in the *Nova Acta Acad. Nat. Cur.* vol. xviii., may be referred to as one of the amplest and most fully illustrated.

§ There is a third group or order, the *Podactinaria* (Edwards and Haime), represented by one genus only, the *Lucernaria*.

cent state.* The *Actinoidea* vary considerably in relative size, and present every state of combination, up to the enormous aggregations of individuals existing in the reef-forming species. The polypes, too, vary greatly in size, from being microscopic to having a diameter of eighteen inches.

The stony Corals present polypes which are readily found, on examination, to present a close analogy to the *Actiniæ*, or Sea-anemones, which are so common on the rocks and in the shallows of our sea-shores; a few observations on these latter animals will therefore enable us to comprehend the nature of this group of polypifera. The Actinia, or *Sea-anemone*, appears, when quiescent, like a subglobular mass of tough jelly, of various tints of crimson, green, blue, or brown (*see Pl.* VI. *fig.* 11); when expanded, it presents a broad disk, surrounded by tentacula, and having in the centre a corrugated surface, which is contracted into a purse-like form.

The Actiniæ are affixed to the rocks by a broad base, but they can detach themselves, and change their position; on many parts of the coast hundreds may be seen, at low water, on the rocks which are left bare by the reflux of the tide. They are carnivorous and very voracious, feeding on the small fish, crustacea, and mollusca that come within their reach. They may be kept for months in sea-water, if supplied daily with meat, which they greedily seize, draw into the sac or stomach, and afterwards eject perfectly colourless, having absorbed the juices and left the tough muscular fibre. The body of the Actinia is highly contractile and full of chambers: the tentacula are hollow tubes, which the animal has the power of filling with sea-water and

* For the classification of these Corals, see Dana's Zoophytes, p. 112; and Edwards and Haime, *loc. cit.* Numerous fossil species are figured and described by Michelin, Iconog. Zoophyt. 4to, 1847.

thus causing them to protrude. The chambers also contain water, with which the whole or any part of the body can be filled; an important agency in enabling the animal to shift its situation from place to place. The accompanying plan of the internal structure of the Actinia (*Lign.* 142) will serve to illustrate these remarks. The surface of the stomach, and even the internal lining of the tentacula, are abundantly furnished with cilia. These zoophytes have no durable skeletons.

LIGN. 142.—ILLUSTRATION OF THE STRUCTURE OF THE ACTINIA.*

a, a, The base by which the Actinia attaches itself. *b, b,* Openings of chambers which communicate with each other and with the tentacula. *c, c,* The tentacula. The surface of the stomach is seen in the centre, arranged in vertical plaits or folds.

18. CARYOPHYLLIA AND TURBINOLIA.—In the small recent coral, *Turbinolia rubra,* we have an example of a single calcareous cup or "calyx," divided by vertical lamellæ or partitions, arranged in a radiated manner. This is the skeleton or stony support of a single polype, which has a double row of tubular tentacula, and bears a great analogy to the Actinia; indeed, the recent animal may be described as an Actinia with a calcareous skeleton, fixed by its base.†

* Cyclopædia of Anatomy and Physiology, p. 614: see also the elaborate and well-illustrated Article on *Polypifera,* by Prof. Rymer Jones, in the same work.

† The beautifully illustrated and cleverly written works of Mr. Gosse, on the Actiniæ and other marine animals found on the Dorset, Devon, and Tenby coasts, are so well known, that we need only to allude to them as being highly important to the lover of natural history who wishes to study these animals. The philosophical comparison of *Cyathina Smithii* (a little coral found on our shores, and the only one) with *Actinia,* in Gosse's "Life," &c., is particularly recommended for study. See also "Sea-side Studies," in Blackwood's Magazine, for 1856-7.

The fossil corals (p. 330, *figs*. 1, 2, 3) possess a similar structure. A beautiful living Turbinolia, which is marked with red and white bands, is shown in *Pl*. VI. *fig*. 8: and a similar Coral with its tentacula expanded,* in *fig*. 14.

In the *Caryophyllia* possessing more than one calyx, each calyx contains an actiniform polype: one of those of *C. fasciculata*, which is of a bright green colour, is represented *Pl*. V. *fig*. 4. In another genus, *Pocillopora*, the investing fleshy integument is beautifully mottled, and the polypes, which are of a blue colour, are terminal, as in the Caryophyllia. A branch, as seen alive in the water, is figured in *Pl*. V. *fig*. 11.

19. MADREPORA.—In the Caryophyllacea, just noticed, the polypes and their containing calyces are of relatively large size; but in the family of branched or arborescent calcareous polypifera called *Madrepores*, the little cups or cells,

LIGN. 143.—RECENT CORALS.

Fig. 1. A branch of *Oculina ramea*. 2. A branch of *Madrepora muricata*. 3. A branch of *Isis hippuris*: *a*, the cortical substance present and covered with pores, which are the cells of polypes; *b*, a branch deprived of its outer covering, and exposing the articulated axis or stem.

with radiating lamellæ, in which the polypes are situated, are of small size. When the animals die, and the outer

* *See especially* Quoy and Gaimard's Voyage de l'Astrolabe (Atlas), *and Dana's Zoophytes* (Atlas), for figures of corals drawn from nature.

fleshy or gelatinous investment perishes, the coral is found to be studded over with elegant, lamellated, stellular cells, variously formed and arranged in the different genera and species. In some the cells are very distinct; as in a Mediterranean species, the *May-blossom Coral* (*Oculina ramea*, *Lign.* 143, *fig.* 1); in others they are exceedingly minute, as in the common Madrepore (*M. muricata*, *Lign.* 143, *fig.* 2), from the West Indies: the white-branched corals, so numerous in collections, belong for the most part to this group.

When alive in the water, the Madrepores are invested with a fleshy integument of various colours; and each cell is occupied by a polype, as in the zoophytes previously described. The appearance of a living Madrepore (*Madrepora plantaginea*), with the polypes protruded, is shown in *Pl.* VI. *fig.* 5, and will serve to convey a faint idea of the beautiful appearance of the live corals in their native element.

20. Fungia.—The white, disciform, lamellated corals, called Sea-mushrooms, or *Fungiæ*, from their fancied resemblance to fungi, are among the most elegant and abundant forms of corallaria in the cabinets of collectors. These, in a living state, are covered with a thick, transparent, jelly-like substance, which fills up all the numerous radiating interstices of the calcareous laminæ; in the central depression of the fleshy mass is situated a large polype with tentacula; in the Fungia, there is but one polype—but one focus of vitality. In the *Fungia actiniformis* (*Pl.* VI. *fig.* 15), the polype strikingly resembles the Actinia; the whole surface of the disk is covered with long, tubular, conical, prehensile tentacula, with minute terminal apertures, and striated, transverse, muscular bands; these tentacula are protruded by the injection of water from below, as in the Actinia. In the Fungia the stony base is secreted from the inferior surface of the soft substance, and is either attached or cemented, as it were, to the rock, or lies free on the sea-bed.

21. Astræa, Pavonia, &c.—In some of the large stony

corals, the cells of the polypes are very numerous, and the coralline mass presents a surface beautifully marked with stellular impressions. The *Astræa viridis* is here represented as seen alive in the sea (*Pl.* VI. *fig.* 13). The polypes in this coral are of a dark-green colour, six lines in length, and are protected by deep, laminated, polygonal cells, two lines in diameter. They are striated with longitudinal and transverse bands, and connected by a fleshy layer which covers the dark-brown coral; some of the polypes are here shown expanded, and others contracted. In this magnified view (*Pl.* VI. *fig.* 10) of a single polype, the tentacula are seen expanded, or disposed around the prominent mouth. The appearance of groups of Astrææ, and other corals, when viewed while the animals are alive and in activity, is most beautiful; looking down through the clear sea-water, the surface of the rock appears one living mass, and the congregated polypes present the most diversified and vivid hues.*

The *Pavonia* are those corals which have deep and isolated cells, each containing a large depressed polype, very similar in its appearance and structure to the Actinia. *Pl.* VI. *fig.* 11, represents a group of cells containing polypes of the *P. lactuca*, from the shores of the South Sea islands. The polypes are of a green colour, and there is a connecting, transparent, fleshy substance, which extends over the extreme edges of the foliated expansion of this elegant zoophyte.

22. MÆANDRINA CEREBRIFORMIS; or *Brain-coral.*—The large hemispherical corals, having the surface covered with meandering ridges and depressions, disposed in a manner somewhat resembling the convolutions of the brain, are well known by the name of the *Brain-stone Coral* (*Lign.* 144). In a living state the mass is invested with a fleshy substance, variously coloured, and having numerous, short, conical, polypiform, confluent cells, arranged in rows between the

* Dana's Zoophytes, p. 29.

ridges. This zoophyte sometimes attains considerable magnitude; a very beautiful specimen in the British Museum is four feet in circumference. The base of the Mæandrina, like that of other corals, is adherent to the rock. As one

LIGN. 144—BRAIN-STONE CORAL.

(*Mæandrina cerebriformis.*)

fleshy mass expires, another appears, and gradually expands, pouring out its calcareous secretion on the parent mass of coral; thus successive generations go on accumulating vast beds of stony matter, and laying the foundations of coral-reefs and islands. We may compare, observes Sir C. Lyell,* the operation of the zoophytes in the ocean to the effects produced on a smaller scale on land by the plants which generate peat, where the upper part of the *Sphagnum*, or peat-moss, vegetates while the lower is entering into a mineral mass, in which the traces of organization remain when life has entirely ceased. In these Corals, in like manner,

* Principles of Geology.

the more durable materials of the generation that has passed away serve as the foundation over which their progeny spreads successive accumulations of calcareous matter.

23. ALCYONARIAN ZOOPHYTES: GORGONIA, OR SEA-FAN.—The *Gorgonia flabellum*, or Venus's fan (*Lign.* 145), is a flexible zoophyte inhabiting almost every sea, and frequently attaining a height of four or five feet. When fresh from the water it is of a bright yellow colour. This species exhibits the usual structure of the corticiferous polypifera, or zoophytes having an internal axis or skeleton of a tough horny consistence, with an external envelope or rind entirely investing the former. The Gorgoniæ present great diversity of form and appearance. This specimen from the West Indies (*Pl.* VI. *fig.* 2) is remarkable for its richness of colour, being a bright yellow, spotted with red; this species (*Pl.* VI. *fig.* 3), from the Mediterranean, has its pendant branches very elegantly disposed, and is of a purplish-lake colour; in both these examples the axis is black, and of the consistence of tough horn. Another beautiful species from the Mediterranean (the *Gorgonia patula* of Ellis) is of a bright red, and has the openings for the polypes disposed in two rows; a portion, highly magnified, is here represented (*Pl.* V. *fig.* 3), and exhibits several polypes in different states of protrusion.

These flexible Alyconaria are mostly attached to the rocks by an extended base, the surface of which is usually deprived of the fleshy substance that invests the other parts. The stem which springs from the base, although in a few species simple, generally divides into branches, which are exceedingly various in their size and distributions:—double, single, anastomosed, pinnated, straight, and pensile; and the stems are either compressed, flat, angular, or cylindrical; but in all these modifications the same structure prevails—an axis and an external crust or rind. The former is either horny, elastic, flexible, brittle, or pithy, seldom stony, and of a dark colour; the latter a soft or tough fleshy substance, studded with pores, from which the polypes issue; this rind becomes

LIGN. 145.—GORGONIA FLABELLUM; *one-twentieth nat. size.*

earthy and friable when dried. In the *Isis*, which may be described as a Gorgonia with a jointed stem, this structure is well displayed, as in this branch of *Isis hippuris* (*Lign. fig.* 3, p. 624), in which a portion of the cortical part is removed, and the axis exposed. In the water the various species present the most vivid hues of red, green, violet, and yellow. The Gorgoniæ inhabit deep water, and are found in every sea; but certain species appear to be restricted to tropical climates. The Sea-pens (*Pennatulæ*) have a fleshy feather-like polypary, with a bony axis, and live unattached, floating free in the water, or lying on the sea-bottom, *more or less imbedded* in sandy mud.

Numerous species of the Asteroid Polypes, especially Alcyonium, Gorgonia, Pennatula, and their congeners, have calcareous spicules * imbedded in their leathery or fleshy integument, as in the Sponges. Horny spicules have been discovered in some Actiniæ.†

24. THE RED CORAL; *Corallium rubrum.*—Among the Alcyonarian or Asteroid Zoophytes are a few genera having an axis composed of a calcareous stony substance; and one genus possesses a skeleton of so beautiful a colour, and susceptible of so fine a polish, as to be largely employed for ornamental purposes. The Red Coral is a branched zoophyte, somewhat resembling in miniature a tree deprived of its leaves and twigs. It seldom exceeds one foot in height, and is attached to the rocks by a broad expansion or base. It consists of a brilliant red stony axis, invested with a fleshy or gelatinous substance of a pale blue colour, studded over with stellular polypes. This figure (*Pl.* V. *fig.* 9) represents a branch of "Coral" with several polypes, highly magnified, as seen alive in the water. The cortical or fleshy substance is removed at the extremities of the branch, and the red stony axis exposed. As the cells of the polypes are only composed of the soft animal matter which rapidly undergoes decomposition after death, no traces of their structure remain on the durable skeleton.

The Red Coral, as is well known, is of a very hard and durable texture; it is obtained by dredging in different parts of the Mediterranean and Eastern seas, and forms an important article of commerce. It varies much in hue, according to its situation in the sea: in shallow water it is of the most beautiful colour, a free admission of light appearing necessary for its full development. It is of slow growth; eight or ten years, in a moderate depth of water, being necessary for it to reach maturity. Arrived at this period,

* See Histological Catalogue, Roy. Coll. Surg. vol. i. p. 222, pl. 13; and Dana's *Zoophytes*, p. 53.

† Histol. Catal. p. 226.

it extends but very slowly, and is soon pierced on all sides by those destructive animals which attack even the hardest rocks: it loses its solidity, and a slight shock detaches it from its base. Becoming the sport of the waves, the polypes perish, their brilliant skeleton is exposed, and cast upon the shore; the bright colour soon disappears, and the coral, reduced to fragments by the attrition of the waves, becomes mixed with the remains of shells and other marine exuviæ: in this state it is drifted inland by the winds,* and assists in forming those accumulations of the spoils of the sea, which constitute many of the modern conglomerates described in a previous lecture (pp. 83 and 90).

25. Tubipora.—This group of the Alcyonarian corals is well known from the elegance and beauty of one species (*Sarcinula musicalis*, or *Organ-pipe coral*), which is common in most collections. This zoophyte is composed of parallel tubes, united by lateral plates, or transverse partitions, placed at regular distances (*Pl.* VI. *figs.* 7, 9); in this manner large masses, consisting of a congeries of pipes or tubes, are formed. When the animalcules are alive, each tube contains a polype of a beautiful bright green colour, and the upper part of the surface is covered with a gelatinous mass formed by the confluence of the polypes; a magnified view of a polype and of sections of two tubes is here represented (*Pl.* VI. *fig.* 7). This species occurs in great abundance on the coast of New South Wales, of the Red Sea, and of the Molucca Islands, varying in colour from a bright red to a deep orange. It grows in the shape of large hemispherical masses, from one to two feet in circumference; these first appear as small specks adhering to a shell or rock; as they increase, the tubes resemble a group of diverging rays, and

* The term "æolian" has been aptly applied by Col. Nelson to the terrestrial formations resulting from the drifting action of the winds. See Quart. Journ. Geol. Soc. vol. ix. p. 206.

at length other tubes are produced on the transverse plates, thus filling up the intervals, and constituting a uniform tubular mass; the surface being covered with a green fleshy substance, beset with stellular animalcules. The protruded polype of another beautiful species of Tubipore (*Tubipora rubeola*) is represented magnified, *Pl.* 6, *fig.* 4; and a view of an expanded polype of the same seen from above, in *fig.* 6; the polype of another species of Tubipore is represented in *fig.* 12.

26. GEOGRAPHICAL DISTRIBUTION OF CORALS.—Having described a few of the principal varieties of the Polypifera, I will next consider the geographical distribution of these zoophytes; and subsequently review the important physical changes effected by creatures so minute, and apparently so incompetent to produce any material alteration in the earth's surface.

The Corals are inhabitants of the ocean; many species prefer the immediate influence of atmospheric changes, and are seen on the rocks and plants left bare by the reflux of the tide, sometimes in such profusion that the whole surface appears one animated mass. At the period of the great equinoctial tides, when the sea retires from the rocks which it has overflowed for many preceding months, the Polypifera, when the waters first recede, are full of vigour, but languish as they lose their moisture, and perish if they remain long uncovered by the sea.

Some kinds are situated on the southern slope of the rocks; others, on the contrary, are attached to the opposite aspect, and never to the former. The larger forms are rarely found in places exposed to violent currents; it is in the hollows of the rocks, in submarine grottos, in the shelter of large and solid masses, that these species attach themselves. Many appear fitted to enjoy the powerful action of the surges, their pliant branches bending to the movements of the waves, and floating in the agitated water; while others form immoveable rocks, which increase slowly but surely, until they become elevated above the surface of the waters, and constitute reefs and islands, as I shall hereafter describe.

The distribution of the Anthozoa is not solely regulated by the relative depths of the water; like plants, they vary with the climate, and in cold latitudes the *Alcyonaria* and some *Hydroida* are alone to be met with. On the coasts of Britain, between 50° and 60° of north latitude, only one or two minute stony corals represent, with the common *Actinia*, multitudinous in its individuals and varieties, and a few allied but rarer genera, the *Actinoidea;* whilst the two other groups present many forms. As we proceed southwards the numbers of each group increase; it is not, however, before the 34th degree of northern latitude that the Corals become developed to the grandeur and importance which they afterwards attain, to the extent of a parallel southern latitude, except, in the waters of the Atlantic, around the Bermuda Islands, where corals abound, owing to the temperature induced by the influence of the Gulf-stream.* It is therefore within the tropics, in a zone of more than 60 degrees expansion, that these beings, scarcely visible to the naked eye, hold their empire in a medium whose temperature knows no change; and from the depths of the ocean elevate those immense reefs that may hereafter form a communication between the inhabitants of the temperate zones.†

* Mr. Dana states that 60° Fahrenheit limits the growth of Corals. Corals occur, however, at the Bermudas, which are in lat. 33°, four or five degrees beyond the Coral-limits, because of the increased temperature of the water occasioned by the Gulf-stream; on the other hand, there are no Coral-reefs around the Galapagos Islands, which are situated under the equator, because of the cold waters of the southern current up the South-American coast, by which the temperature of the ocean is reduced to 60°, though 20° further to the west the waters are at 84°. (See Mr. Dana on "Areas of Subsidence in the Pacific Ocean," American Journal of Science, vol. xlv. p. 131.)

† For detailed remarks on the geographical distribution of the Coral-

The Sponges are similarly prolific to a vast extent, presenting enormous masses and fantastic shapes, in the Mediterranean and tropical seas; whilst a stunted and limited, though still varied and numerous, group of Spongiadæ grow around the coasts of the temperate and colder seas. The Sponges frequent the fresh waters also; and the study of the growth and structure of the *Spongilla* has enabled naturalists of late to add much to our knowledge of these low forms of life.

27. Appearance of the living Corals.—In some parts of the sea the eye perceives nothing but a bright sandy plain at the bottom, extending for many hundred miles; but in the Red Sea, the whole bed of this extensive basin of water is absolutely a forest of submarine plants and zoophytes. Here are bryozoa and sponges, sertulariæ, gorgoniæ, madrepores, fungiæ, and other anthozoa, with fuci, algæ, corallines, and all the variety of marine vegetation, covering every part of the bottom, and presenting the appearance of a submarine garden of the most exquisite verdure, enamelled with animal forms, resembling, and even surpassing in splendid and gorgeous colouring, the parterres of the East.

Ehrenberg, the distinguished German naturalist, who has laboured so assiduously and successfully with pen and pencil in illustrating the natural history of the Infusoria and Foraminifera, was so struck with the magnificent spectacle presented by the living Corals in the Red Sea, that he exclaimed with enthusiasm, "Where is the paradise of flowers that can rival in variety and beauty these living wonders of the

larian Zoophytes, the reader is referred to the works of Lamouroux, Blainville, Dana, Darwin, and others. With regard to the Bryozoan Zoophytes, an excellent synopsis of their distribution in depth, according to the marine zones, on the British coast, may be seen in Mr. Alder's "Catalogue of the Zoophytes of Northumberland and Durham," Trans. Tyneside Nat. Field-club, vol. ii. p. 98, and in the Microscop. Journal, 1857, p. 242. To Mr. Allman's beautiful monograph of the Fresh-water Bryozoans (Ray Society, 1856) we have already referred.

ocean?" Some have compared the appearance to beds of tulips or dahlias; and, in truth, the large fungiæ, with their crimson disks and their purple and yellow tentacula, bear no slight resemblance to the latter.

The impressions produced upon first seeing a grove of live Corals are thus vividly portrayed by Mr. Jukes.*—

"In a small bight of the inner edge of this reef was a sheltered nook, where the extreme slope was well exposed, and where every coral was in full life and luxuriance. Smooth round masses of mæandrina and astræa were contrasted with delicate leaf-like and cup-shaped expansions of explanaria, and with an infinite variety of branching madreporæ and seriatoporæ, some with mere finger-shaped projections, others with large branching stems, and others again exhibiting an elegant assemblage of interlacing twigs, of the most delicate and exquisite workmanship. Their colours were unrivalled,—vivid greens, contrasting with more sober browns and yellows, mixed with rich shades of purple, from pale pink to deep blue. Bright red, yellow, and peach-coloured nulliporæ clothed those fleshy masses that were dead, mingled with beautiful pearly flakes of eschara and retipora; the latter looking like lace-work in ivory. In among the branches of the corals, like birds among trees, floated many beautiful fish, radiant with metallic greens or crimsons, or fantastically banded with black and yellow stripes. Patches of clear white sand were seen here and there for the floor, with dark hollows and recesses, beneath overhanging masses and ledges. All these, seen through the clear crystal water, the ripple of which gave motion and quick play of light and shadow to the whole, formed a scene of the rarest beauty, and left nothing to be desired by the eye, either in elegance of form or brilliancy and harmony of colouring."

The vast abundance and variety of animal life in these Coral formations is thus vividly depicted by the same naturalist:—

"A block of coral-rock, that was brought up by a fish-hook from the bottom of one of our anchorages, had its surface covered with brown, crimson, and yellow nulliporæ, many small actiniæ, and soft-branching corallines, sheets of flustra and eschara, and delicate retiporæ, looking like beautiful lace-work carved in ivory. There were several small sponges and alcyonia, sea-weeds of two or three species, two species of

* "*Narrative of the Surveying* Voyage of H. M. S. Fly, in 1842—*1846;*" *by J. B. Jukes,* Naturalist to the Expedition, vol. i. p. 117.

comatula, and one of ophiura, of the most delicate colours and markings, and many small, flat, round corals, something like nummulites in external appearance. On breaking into the block, boring shells of several species were found buried in it: tubes formed by annelida pierced it in all directions, many still containing their inhabitants: while two or three worms, or nereis, lay twisted in and out among its hollows and recesses; in which likewise were three small species of crabs. This block was not above a foot in diameter, and was a perfect museum in itself, while its outside glared with beauty from the many brightly and variously coloured animals and plants. It was by no means a solitary instance; every block that could be procured from the bottom in from 10 to 20 fathoms was like it. What an inconceivable amount of animal life must be here scattered over the bottom of the sea, to say nothing of that moving through its waters; and this through spaces of hundreds and hundreds of miles! Every corner and crevice, every point occupied by living beings, which, as they become more minute, increase in tenfold abundance." *Ibid.* vol. i. p. 17.

28. Coral-reefs.—The vast accumulations of calcareous rocks in tropical seas, resulting from the consolidation of the disintegrated skeletons of polypifera, have already been alluded to, but the physical changes that are produced by such apparently inadequate means require further consideration, since they illustrate the formation of the coralline rocks of the secondary and palæozoic epochs.

Mr. Juke's description, above quoted, of a composite block of Coral illustrates this point; and in the little *Flustræ* of our coast (p. 612), delicate and brittle though they be, we perceive the elements of those important changes to which the large lamellar corals of tropical seas are giving rise. In the specimen before us, you may observe that the base of the mass of a *Flustra foliacea*, which is about six inches in diameter, is already consolidated by an aggregation of sand, that has filled up the interstices. On the surface are numerous parasitical shells and Corals, and between the convolutions of its foliated expansions, echini, crustacea, and other animals have taken shelter; while sand and mud have invested every cranny of the lower third of the specimen, ·edded serpulæ, sabellæ, and fragments of many species of shells. It is evident that, were the whole specimen filled up and surrounded by detritus, as it shortly would be at the bottom of the sea, a solid block would be formed, exhibiting, when broken, the remains of the Flustra, impacted in a conglomerate of sand, shells, and zoophytes. Thus we perceive that even the delicate, friable skeletons of t e Flustræ of our shores may become the nucleus of a solid rock; and in the process described, we have, as it were in miniature, the formation of a Coral-reef.*

28.* Coral-reef of Loo Choo.—But it is in tropical seas that the *Mæandrinæ*, *Astrææ*, *Caryophylliæ*, and other stony Corals form those immense masses, which not only give rise to groups of islands in the bosom of the ocean, but are gradually forming tracts of such extent that a new continent may spring up where the fabled Atalantis is supposed to have once flourished. From the many interesting descriptions of the nature and formation of Coral-reefs and islands that have been published by our voyagers, I select the following account, by Captain Basil Hall, of a Coral-reef near the great island of Loo Choo:—

"When the tide has left the rock for some time dry, it appears to be a compact mass, exceedingly hard and rugged: but as the water rises, and the waves begin to wash over it, the polypes protrude themselves from holes which were before invisible. These animals are of a great variety of shapes and sizes, and in such prodigious numbers, that in a short time the whole surface of the rock appears to be alive and in motion. The most common form is that of a star, with arms or tentacula, which are moved about with a rapid motion in all directions, probably to catch food. Others are so sluggish that they may be mistaken for pieces of the rock, and are generally of a dark colour. When the coral is broken above high-water mark, it is a solid, hard stone; but, if any part of it be detached at a spot where the tide reaches every day, it is found

* Some reefs are nearly wholly composed of Serpulæ and Serpuloid shells; others of Nullipores and similar calciferous sea-plants; and in all reefs the Bryozoa supply much material, though seldom found in such masses as in the *Crag, and in the* Maestricht and Faxoe Chalk.

to be full of polypes of different lengths and colours; some being as fine as a thread, of a bright yellow, and sometimes of a blue colour. The growth of coral appears to cease when no longer exposed to the washing of the sea. Thus a reef rises in the form of a cauliflower, until the top has gained the level of the highest tides, above which the animalcules have no power to advance, and the reef of course no longer extends upwards."

29. CORAL-ISLANDS.—Kotzebue, Flinders, Quoi and Gaimard, Darwin, Dana, Jukes, and others have severally described the formation of Coral-islands; the following is an abstract of their observations:—

The coral-banks are everywhere seen in different stages of progress: some are become islands, but not yet habitable; others are above high-water mark, but destitute of vegetation; while many are overflowed with every returning tide. When the polypes of the corals at the bottom of the ocean cease to live, their skeletons* still adhere to each other; and, the interstices being gradually filled up with sand and broken pieces of corals and shells, washed in by the sea, a mass of rock is at length formed. Future races of these animalcules spread out upon the rising bank, and in their turn die, and thus increase and elevate this wonderful monument of their existence.

The reefs which raise themselves above the level of the sea are usually of a circular or oval form, and surrounded by a deep and oftentimes unfathomable ocean. In the centre of each, there is generally a shallow lagoon with still water, where the smaller and more delicate kinds of zoophytes find a tranquil abode; while the stronger species live on the outer margin of the isle, where the surf dashes over them. When the reef is dry at low water, the coral-animals cease to increase. A continuous mass of solid stone is then seen, composed of shells, echinoderms, and fragments of corals, united by calcareous sand, produced by the pulverization of the shells and of the friable polyparia. Fragments of coral-limestone are thrown up by the waves; these are cracked by the heat of the sun, washed to pieces by the surge, and drifted on the reef. After

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* The chemical constitution of the polyparies of Alcyonarian and Actinoidean Corals is treated of by Prof. Dana in his "Zoophytes," p. 56, and by Prof. B. Silliman, jun., in the Appendix to that work. Mr. *B. Silliman* has shown, contrary to expectation, that they contain a much *larger proportion* of fluorine than of phosphoric acid.

this the calcareous mass is undisturbed, and offers to the seeds of the cocoa, pandanus, and other trees and plants, floated thither by the waves, a soil on which they rapidly grow, and overshadow the white dazzling surface. Trunks of trees, drifted by currents from other countries, find here at length a resting-place, and bring with them some small animals, as lizards. insects, &c. Even before the trees form groves or forests, sea-birds nestle there, and strayed land-birds find refuge; and at a still later period, Man takes possession of the newly-created country. It is in this manner that the Polynesian Archipelago has been formed.*

The immediate foundations of these islands are ancient coral-reefs, and some of these, in all probability, are based on the cones or craters of submarine volcanos long since extinct; and others on the lofty peaks of a submerged continent which has undergone a slow subsidence, and thus admitted of the growth of successive generations of the coral-secreting zoophytes, and the formation of immense beds and zones of submarine coral-rocks. There is another circumstance worthy of remark: most of these islands have an inlet through the reef† opposite to the large valleys of the neighbouring land, whence numerous streams issue and flow into the sea; an easy ingress is thus afforded to vessels, and the means of obtaining an abundant supply of fresh water readily offered.

Of the immense extent of the changes here contemplated we may form some idea from the facts stated by competent observers, that in the Indian Ocean, to the south-west of Malabar, there is a chain of reefs and islets 480 geographical miles in length; on the east coast of New Holland, an unbroken reef 350 miles long; between that and New Guinea, a Coral-formation which extends upwards of 700 miles; and that Disappointment Islands and Duff's Group are connected by 600 miles of Coral-reefs, over which the natives can travel from one island to another.

30. Formation of Coral-islands.—From the grand scale on which these operations have been carried on in the Pacific, and the powerful volcanic action of which those latitudes have been the theatre, as shown by the elevatory

* At least so much of it as can be truly said to be of late origin. Some of the islands, on the other hand, are probably the coral-crested *sinking peaks of a mountainous* and possibly once continental area.

† *Analogous to the* broken side of a crater.

movements to which the neighbouring continents have been subjected, the extremely small extent of dry land in that world of waters is a very striking phenomenon. This remarkable fact was supposed by Sir C. Lyell* to admit of explanation, on the supposition that a gradual subsidence had been going on for ages over a vast area of the bed of the Pacific, which occasioned the solid materials produced by the Coral-zoophytes to sink down beneath the waters, and therefore no considerable additions were made to the dry land above the level of the sea: the Polynesian Archipelago and the submerged Coral-reefs alone indicating the stupendous changes effected by zoophytal agency. This opinion has been confirmed by the observations of Mr. Darwin, whose explanation of the mode in which the formation of Coral-islands takes place is a beautiful example of philosophical induction.

The coral-reefs are described by Mr. Darwin as of three distinct kinds, arising from the different circumstances attending their production. First, *Atolls*; † secondly, *barrier-reefs*, which are ridges of coral either extending in straight lines in front of the shores of a continent or large island, or encircling a group of small islands, and separated from the land by a deep channel of water; thirdly, *fringing-reefs*, or banks of coral superimposed on the slopes of the adjacent land, and at no great distance from the shore.

By the gradual subsidence of the land, and the coincident upward growth of the corals, fringing-reefs are gradually converted into barrier-reefs, and the latter into Atolls. Hence it is inferred, that coasts merely fringed by reefs have not subsided to any considerable amount, but either have remained stationary, or have been upheaved, since the growth of the coral. When a barrier-reef, encircling an island, gradually sinks down, the corals go on growing vigorously upwards; but, as the island sinks, the water gains inch by inch on the shore, and the mountain-tops at length become separate islands, within one great reef; and ultimately the highest pinnacle disappears, and a perfect Atoll is formed. Hence lagoon-islands, having originated from encircling barrier-reefs, resemble them in

* Principles of Geology, 1st edition.

† The circular or lagoon islands are so called by the natives.

general size and form, and in the manner in which they are grouped together; and they may be regarded as outline-charts or models of the sunken islands they now surmount. By this theory of the upward growth of polypifera during the subsidence of the land on which they are based. Mr. Darwin satisfactorily explains all the leading phenomena of those marvellous structures, the barrier-reefs, and of those fairy coral-islands that begem the vast expanse of the Pacific, and flourish in the midst of its mighty billows. The narrow belt of land of these insular zones, frequently but a few hundred yards wide, is surrounded by a deep and often unfathomable ocean, and encloses a lake of tranquil water; it is crowned with cocoa-nut trees, clothed with a luxuriant tropical vegetation, and begirt with a beach of glittering sand, on which are constantly dashing the snow-white breakers of the azure sea. Nowhere, as Mr. Darwin beautifully remarks, can be found such wonderful proofs of the power of vitality to repel the influence of mechanical force; for the breakers far exceed in violence those of our temperate regions, and it is impossible to behold them without feeling a conviction, that rocks of quartz or granite would speedily be demolished by such irresistible agents; * and yet there stand, immoveable, those marvellous monuments—

"Raised by the feeblest creatures in existence,"

unscathed by the raging billows, and smiling with perpetual verdure,— the oases of that vast wilderness of waters! †

31. Montgomery on Coral-islands.—The formation of islands and continents by the vital energies of countless myriads of minute beings, the unconscious living instruments of stupendous physical changes, is invested with so much of the sublime and the marvellous, as to form a subject alike calculated to engage the attention of the philosopher and to excite the imagination of the poet; and I am tempted to relieve this detail with the following beautiful lines by James Montgomery:‡—

* See Mr. Darwin's delightful volume, "On the Structure and Distribution of Coral Reefs."

† The striking isolation of these tiny specks of land on the vast expanse of ocean can be best realized by a survey of Mr. Wyld's great Model of the Earth.

‡ *From "The Pelican Island,"* by James Montgomery.

"I saw the living pile ascend,
The mausoleum of its architects,
Still dying upwards as their labours closed;
Slime the materials, but the slime was turned
To adamant by their petrific touch.
Frail were their frames, ephemeral their lives,
Their masonry imperishable. All
Life's needful functions, food, exertion, rest,
By nice economy of Providence,
Were overruled to carry on the process,
Which out of water brought forth solid rock.
Atom by atom, thus the mountain grew
A Coral-island, stretching east and west;
Steep were the flanks with precipices sharp,
Descending to their base in ocean-gloom.
Chasms few, and narrow, and irregular,
Form'd harbours, safe at once and perilous;
Safe for defence, but perilous to enter.
A sea-lake shone amidst the fossil Isle,
Reflecting in a ring its cliffs and caverns,
With heaven itself seen like a lake below.
Compared with this amazing edifice,
Raised by the feeblest creatures in existence,
What are the works of intellectual man,
His temples, palaces, and sepulchres?
Dust in the balance, atoms in the gale,
Compared with these achievements in the deep,
Were all the monuments of olden time!
Egypt's grey piles of hieroglyphic grandeur,
That have survived the language which they speak,
Preserving its dead emblems to the eye,
Yet hiding from the mind what these reveal;
Her Pyramids would be mere pinnacles,
Her giant statues, wrought from rocks of granite,
But puny ornaments for such a pile
As this stupendous mound of catacombs,
Fill'd with dry mummies of the builders, worms!"

32. Fossil Zoophytes.—The conditions under wh corals and other zoophytes are preserved in the min *kingdom,* and the formation of conglomerates from the de

of corals and shells, have been described in the previous lectures; in this place I shall offer a cursory review of the geological distribution of fossil zoophytes, without entering upon details which will be found more or less fully exemplified in the account of the organic remains of the respective systems of deposits.

The coral-limestones now forming on the shores of the Bermuda and Bahama Islands (see p. 83), and similar conglomerates on those of the Isle of Ascension (p. 89), prove that at the present time accumulations of calcareous stone are going on analogous in character to many of the fossiliferous deposits of the Chalk, Oolite, and other ancient formations. Mr. Darwin has observed a similar effect in the Pacific, where disintegrated coral-reefs give rise to vast deposits of calcareous detritus, which, when dry, closely resembles soft chalk. In the West Indies, blocks of silicified mæandrinæ, astrææ, and other reef-forming species are abundantly distributed in the superficial alluvium of Antigua and other islands. The pliocene, or newer tertiary of Palermo, abounds in corals,* some of which belong to species that still inhabit the Mediterranean. In the Crag, there are a few species of extinct corals,† with many forms of Bryozoa, chiefly now unknown as natives of the adjacent seas. The miocene of North America contain many kinds of zoophytes, some of which appear to be peculiar to those strata.‡ In the eocene deposits there are several extinct genera and many species. Excepting four genera in the Crag,§ we have in England no fossil corals of younger age

* Michelotti, *Spec. Zoophyt. Diluv.*, and Michelin, *Iconographie Zoophytologique*, have figured and described many of these.

† See Edwards and Haime's Monograph of Brit. Foss. Corals, Palæont. Soc. 1850

‡ See report on Corals from the Tertiary Formations of North America, by Mr. Lonsdale; Geol. Soc. Journal, vol. i. p. 495.

§ And a Millepore in the Pleistocene beds of Ayrshire.

than those of the Bracklesham and London clays of eocene age.* It is interesting, however, to observe that the miocene tertiaries of Austria contain reefs both of true coral sand of the vegetable corallines (Nullipores); the former proving that in tertiary times the Vienna basin was a continuous sea with the present area of the Red Sea, the nearest

LIGN. 146.—FOSSIL ZOOPHYTES; FROM FARRINGDON, BERKS.

Fig. 1. *Manon peziza*. 3. *Verticillipora anastomosans*.
2 and 4. *Manon*. 5. *Tragos?*

point where such corals are now found, and which was probably a portion of the channel of some old north-going current of warm water, like the existing Gulf-stream.† In the Chalk-formation of England corals ‡ are not abundant; throughout vast areas of the fine white chalk there are no considerable beds of corals, nor appearance of coral-reefs; the species

* *Edwards* and Haime, *loc. cit.* † Unger, Proceed. Vienna Acad. 1856.
‡ Edwards and Haime, op. cit. p. 44.

for the most part small and delicate (p. 330). There are, however, numerous genera and species of the bryozoa and sponges in the chalk and its associated beds.

The manner in which the remains of polypifera are distributed in our white chalk involves an interesting inquiry; they occur promiscuously intermingled with shells, echini, and fishes; we find no beds of corals—nothing to point out the former existence of reefs. This phenomenon, however, is in accordance with the general lithological character of the Chalk-formation, and the nature of its organic remains; both of which indicate a profound ocean. As polypifera can only exist at moderate depths, the occurrence of coral-reefs was not to be expected, except in those areas which may be supposed to have been formed in the shallows, or near the sea-shores.

The cretaceous coral-reefs evidently existed further south, for the Hippurite-limestone of the south of Europe and the Gosau-chalk of the Eastern Alps abound with corals.* Corals are not uncommon also in the Maestricht chalk.

In the Danish islands of Seeland and Möen, the flinty chalk is covered by bryozoan limestone, some portions of which form a compact building-stone, while others are mere masses of bryozoa cemented together by a white detritus. These beds belong to the Chalk-formation; for, although they abound in univalve shells not common in our cretaceous strata, yet a large proportion of the sponges, bryozoa, echinites, and belemnites are identical with those of the English Chalk. Sir C. Lyell therefore infers, "that the peculiarity of the fossil fauna of Faxoe † was produced more by geographical conditions, such, for example, as the

* Michelin, Icon. Zoophyt. plates 64 to 73; and Reuss, Trans. Vienna Acad. vol. vii.

† A locality in Denmark, where these deposits are best displayed. See Geol. Trans. 2nd ser. vol. v. p. 243.

local shallowness of that part of the cretaceous sea, than by any general change in the creatures inhabiting the ocean, effected in the period that may have intervened between the formation of the White Chalk and the Faxoe limestone." The same may be said of the bryozoiferous strata at Maestricht, which contain also numerous nullipores.

The remains of sponges are very frequent in the chalk,* and in many places not only do they swarm in the limestone, but also in the flints; so that almost every nodule encloses a sponge or other poriferous zoophyte. The Upper Greensand in some localities contains immense numbers of porifera.† The gravel-pits, as they are called, in the neighbourhood of Farringdon,‡ in Berkshire, are extremely pro-

LIGN. 147.—FOSSIL ZOOPHYTE FROM THE UPPER OOLITE AT CAEN.

(Chenendopora fungiformis, Lamouroux.)

lific in fossils of this kind. These beds consist of a coarse

* Michelin, *Icon. Zooph.* plates 28 to 42.

† Miss Benett's *Catal. Wiltshire Fossils*, 4to, 1816.

‡ See Mr. Austen's Memoir on the Fossiliferous Sands and Gravels of Farringdon, Quart. Journ. Geol. Soc. vol. vi. p. 464; and Mr. D. Sharpe's *Memoir* on the same subject, ibid. vol. x. p. 176.

friable conglomerate, formed of sand, shells, bryozoa, sponges, echinoderms, and the debris of other marine animals, impregnated with iron; some layers of concretionary indurated masses occur, originating from infiltration of carbonate of lime.

They contain myriads of perfect shells and zoophytes; casts of nautili, water-worn and other fossils from the Oolites, belemnites, &c. The *Verticillipora anastomosans* * (*Lign.* 146, *fig.* 3) is a very elegant zoophyte often met with in this locality.

One of the most abundant and perfect of the sponge-like forms is a cyathiform zoophyte called "*Petrified salt-cellar*" by the quarrymen; it is of a porous structure, and the inner surface is covered with oscula, or little openings: it closely resembles the fossil sponge from Caen, figured in *Lign.* 147, which is said also to occur in the Upper Greensand at Warminster.

33. Ventriculites of the Chalk.—A very elegant and interesting family of Zoophytes, illustrated by me in an early memoir (published in the "Linnæan Transactions," vol. xi.), and subsequently named *Ventriculites*,† occurs in the chalk of Kent, Sussex, and Wiltshire in such numbers, and under such dissimilar forms, as to require a passing notice in this place. They abound in some parts of the chalk of Europe; and occur also in the jura-beds of Randen.

The original form of the Ventriculite was that of a funnel, or hollow inverted cone, terminating in a point at the base, whence numerous fibres proceed, by which it was attached to other bodies. The outer integument was reticulated, that is, disposed in meshes like net-work, and the inner surface was studded over with regular openings, the orifices of tubular cells, each of which was probably occupied by a polype. The substance of the polyparium, or frame-work, of this aggregation of animalcules, appears to have been analogous to that of the soft alcyonia,

* Much better figured by Mr. D. Sharpe *loc. cit.* p. 195, pl. 5, fig. 1

† Medals of Creation, vol. i. p. 242; and Mr. J. Toulmin Smith's papers on the Ventriculidæ of the Chalk, *Ann. Nat. Hist.* 2 Ser. vol. i. 1848.

and to have possessed a common irritability, and been able to expand and contract. This opinion is based on the circumstance, that some specimens occur in which the zoophyte is in the form of a nearly flat circular disk, and others in that of a subcylindrical pouch; in the former state the outer reticulated structure is elongated, while in the latter it is contracted and corrugated. The polype-cells are cylindrical and very regular; of these cells the flints often present beautiful casts which appear like rows of minute pillars on the inner surface.

When the flint that fills up the cavity of a Ventriculite can be extracted, it is found to be a solid cone, having its surface studded over with papillæ, which are casts of the orifices of the polype-cells. When the enclosed polyparia in flint-nodules have perished, chalcedony and quartz-crystals, and sometimes crystallized pyrites, are found filling up more or less completely the cavities left by the decayed parts of the zoophyte.*

34. ZOOPHYTES OF THE JURASSIC FORMATION.—The Oolite, as we have previously remarked, abounds in corals, and contains beds of limestone which are merely coral-reefs that have undergone no change but that of elevation from the bottom of the deep, and the consolidation of their materials. The Coral-rag of Wilts presents in fact all the characters of modern reefs; the polypifera belong chiefly to the *Astræidæ*, the genera of which family principally contribute to the formations now going on in the Pacific. Shells, echinoderms, teeth and bones of fishes, and other marine exuviæ, occupy the interstices between the corals, and the whole is consolidated by sand and gravel, held together in some instances by calcareous, in others by silicious, infiltrations. In the chert of the Portland Oolite at Tisbury, Wiltshire, masses of a beautiful silicified coral occur; the polished

* I beg to refer to my paper on a "Microscopical Examination of Chalk and Flint," published in Ann. Nat. Hist. 1845, vol. xvi. p. 73 for a particular account of the silicification of these and other zoophytes. See also *above*, p. 308.

* *Edwards* and Haime, *loc. cit.* p. 75.

section of a fragment is shown in *Lign.* 148, *fig.* 9. Large masses of a cellular coral abound in the limestones of the Great Oolite (*Calamophyllia radiata*). The corals, shells, &c., are of extinct species. Those who have visited districts where the Coral-rag forms the immediate sub-soil, and is exposed to view in the quarries, or in natural sections, must have been struck with the resemblance of these rocks to modern coral-banks. We know that in our present seas all situations and circumstances are not alike favourable to the existence and growth of polypifera; in some parts of the ocean they abound, and in others are altogether wanting. In like manner, in the deposits of the Jurassic formation, which extend over a great part of Europe, and have been formed in a sea of vast extent, beds of coral are not universally distributed, but occur only in certain districts (Nuttheim, for instance); in other words, they occupy the situations which in their native seas presented the conditions required by their peculiar organization.

The Lias contains but very few polypifera; *Isastræa Murchisoni* occurs in the lias of Skye. The Trias only a small number (in the Muschelkalk and Halstadt lime-stone).

35. Corals of the Palæozoic Formations. — The Mountain-limestone of the Carboniferous system, which will come under our notice in the next discourse, abounds in the cellular and lamelliferous zoophytes: * and many of the deposits of the Devonian and Silurian system teem with anthozoan corals,† of peculiar forms, and typical of particular groups of strata. The corals of the Silurian deposits of England ‡ equally prevail in the corresponding strata of North America.§

* Edwards and Haime, Monog. Brit. Foss. Corals, 1852.

† Edwards and Haime, *ibid.* 1853 and 1854; and Ann. des Sc. N. 1848.

‡ Murchison's "Silurian System," vol. ii., and "Siluria," pp. 119 and 212, &c. See also M' Coy's Palæoz. Foss. Cambridge, plates 1 B and 1 C.

§ See Hitchcock's "*Geology* of Massachusetts," and Hall's "*Palæontology of the State of New York.*"

This wide geographical range of the same types of coral-zoophytes seems to indicate a more equal temperature in the

LIGN. 148.—FOSSIL CORALS.*

Fig. 1, 3. Omphyma subturbinata; Wenlock limestone; Dudley.
— 2. Palæocyclus (one of the *Fungidæ*); Dudley.
— 4. Cyathophyllum hexagonum; Devonshire.
— 5. Syringopora geniculata; Mountain-limestone; Mendip Hills.
— 6. Thecosmilia annularis; Coral-rag; Wilts.
— 7. Lithostrotion basaltiforme; Mountain-limestone; Yorkshire.
— 8. Slice of Isastræa oblonga; Portland Oolite; Wilts.
— 9. Slice of Coral-marble (Cyathophyllum); Devonshire.

seas of those remote epochs than at present prevails; for

* For numerous illustrations of Fossil Corals, Sponges, and other *Zoophytes, see* Pictorial Atlas of Fossil Remains, plates xxxiv. to xlv.

the reef-forming genera do not now exist in waters of a temperature under 60°, and are therefore, with the exception of the Bermudas (p. 633), restricted to intertropical regions.

The simple turbinated corals, consisting, like the Fungia and Turbinolia (*Pl.* VI. *figs.* 8 and 15), of a solitary cell (*Lign.* 148, *figs.* 1, 2, 3), are found in great abundance and perfection in the Silurian limestones of Dudley, Wenlock, &c.; and are associated with numerous large composite corals, branched and massive.* The Wenlock limestone (in Norway, Sweden, Russia, and North America, as well as in Britain) contains a genus of singular beauty, and which, from the appearance presented by cross sections, is known by the name of *Chain-coral* (*Halysites catenularius; Lign.* 150, *fig.* 3). The tubes of this coral being oval in section, and arranged perpendicularly side by side in undulating lines, display in the transverse sections elegant markings resembling the anastomosings of delicate chains.

The fossil compound polypifera termed Lithostrotion † and Syringopora, consisting of clusters of parallel tubes, laterally united, form continuous layers, or reefs, in the Mountain-limestone of Ireland and other countries; and on the weathered surface of the stone, the corals stand out in relief as sharp as in the coral-rocks of a recent lagoon.

It is interesting to remark, with respect to fossil corals, that a certain peculiarity of structure distinguishes those of the palæozic formations from the secondary, tertiary, and existing corals. In Mr. Milne Edwards's classification ‡ of the corals proper, or *Zoantharia*, there are four chief orders, of which the *Z. aporosa* and *Z. perforata* belong to the recent Tertiary and Secondary periods; the *Z. tabulata* and *Z. rugosa* being chiefly characteristic of the palæozoic period. In the first two, or neozoic, groups of corals, the *septa*, or vertical plates attached to the inner sides of the cell, are essentially composed of six elements, "being disposed in

* See "Medals," chap. viii., for figures and descriptions of fossil corals; and Dr. Carpenter's "Microscope," chap. xi., for the structure of recent zoophytes.

† *Lithodendron*, "Medals of Creation." *Lign.* 70, pp. 260 and 264.

‡ Monograph (*Pal. Soc.*) *1850*, p. x.

groups corresponding to the six primitive radii, or to a multipl number;" the third order (*Z. tabulata*), in which the septal a is arranged as in the foregoing, but very rudimentary, includes tw genera (*Millepora* and *Heliopora*), two tertiary, and four palæozoic whilst the *Z. rugosa* has a *quaternary* arrangement of the septal and is wholly palæozoic.

36. CORALLINE MARBLES.—Certain limestones, l composed of corals, in which the interstices have bee up by calcareous spar, and the enclosed zoophytes m

LIGN. 149.—SECTION OF FAVOSITES POLYMORPHA;* IN A POLISHED PEBBLE, TORQUAY.

less transmuted into the same substance, are suscept a high polish, and constitute some of the most beau marbles. The elegantly figured limestones of Babbi and Torquay in Devonshire, and those of Clifton in l shire, owe their markings to the petrified zoophytes of they are in a great measure made up. The black m of Kilkenny and Belgium are mottled with varie elegant figures of the purest white, which are secti corals and shells transmuted into calcareous spar.

* *Drawn* by Miss Jane Allnutt from a beautiful specimen in t *session of* Mrs. Allnutt, of Clapham Park.

Many of the pebbles thrown up by the waves on the shore along the coast of Devonshire are water-worn fragments of the coral-limestones of that country, and, when cut and polished, display exquisite sections of the enclosed corals (*Lign.* 149).*

1 2

3

LIGN. 150.—CORALLINE MARBLES.

Fig. 1. Silurian limestone, composed of *Syringopora bifurcata*; Dudley.
— 2. Polished section of a marble formed of *Lithostrotion irregulare*; Derbyshire. (Mountain-limestone.)
— 3. Chain-Coral (*Halysites catenularius*); Dudley (Silurian.)

A reddish marble, beautifully marked by the sections of the enclosed coral-tubes ("corallites"), and susceptible of a

* The form and structure of the species of coral of which a section appears in this *polished pebble* are shown in *Lign.* 86, Medals of Creation, vol. i. p. 258.

good polish, is quarried in some parts of Westmoreland and Derbyshire (*Lign*. 150, *fig*. 2). Mr. Parkinson * ascertained that the hue of this marble may be dependent on the original colour of the coral, which probably was of a reddish hue.

I have mentioned (p. 617), that the earthy matter of the recent corals, like the phosphate of lime in the bones of animals, is secreted by a membranous structure, and that, if the lime be removed by a chemical process, the tissue will be rendered manifest. Few, however, will be prepared to learn, that even in corals which have been entombed in the solid rock for innumerable ages the animal membrane can be detected. To Mr. Parkinson we are indebted for the knowledge of this interesting fact. He immersed a piece of marble (*Lign*. 150, *fig*. 2) in dilute muriatic acid, which has the property of dissolving calcareous earth without affecting animal matter: to employ his own words, "as the calcareous earth dissolved, and the carbonic acid gas escaped, I was much pleased to observe the membranaceous substance appear, depending from the marble in light, flocculent, elastic membranes. Many of these, most unexpectedly, retained a very deep red colour, and appeared in a beautiful and distinct manner, although not absolutely retaining the form of the tubipore." (*Loc. cit.*)

37. Crinoidea, or Lily-shaped animals.†—The Echinites, so numerous in the chalk (p. 338), and the Star-fishes, which are more sparingly distributed in the cretaceous strata, are referable to the same group of marine animals as those to which I would now direct your attention. All these creatures belong to the class *Radiaria*, so named from the different parts of which the animal is composed being arranged symmetrically around the centre. This structure is exemplified in the *Uraster* and *Asterias*, or Cross-fish and Star-fish, that abound on our coasts, and must be familiar to every one. These animals have a central disk, containing the mouth and viscera, from which proceed five long arms or rays; the skeleton is composed of numerous little bones,

* Organic Remains of a Former World, vol. ii. p. 16, pl. I. *fig*. 3.

† Medals of Creation, chap. viii. The *Pictorial Atlas Foss. Rem.* contains numerous figures of Crinoidea (plates XLVI. to LII.). See Müller's elaborate description of *Pentacrinus* Caput-medusæ, &c., Berlin. Transact. 1841, p. 177, &c.

enveloped in a tough integument. These bones, or *ossicula*, are calcareous; and are in close apposition over the body, but are articulated together in regular series along the margins of the rays, which are therefore strong and flexible. A longitudinal furrow extends from the mouth to the extremity of each ray, the sides of which are perforated by alternating rows of pores, for the exsertion of tubular tentacula.

Some kinds of Echinoderms (the *Comatulæ*, or Feather-stars), instead of the five flat rays, have jointed arms, that proceed from a central cup-shaped calcareous base, and divide and subdivide into delicate jointed tentacula, the sides of which are fringed with rows of still smaller articulated pinnæ or processes.* Now, if we imagine a Comatula placed with its mouth upwards, and fixed on the top of a jointed stem by the centre of its dorsal surface (a condition actually existing in the young Comatulæ), we have the essential type of the Crinoideans, or Lily-shaped animals, so named from a fancied resemblance of some of the species when in a state of repose to a closed lily. This family is not abundant at the present day; its existing representatives are a few small species (with or without stalks), on the British and European coasts, a more numerous series of large Comatulæ in the tropical seas, and by the rare fixed crinoid (*Pentacrinus Caput-Medusæ*) inhabiting the seas around the West Indies. Of this elegant and scarce representative of the seas around the West Indies, and of this sole representative of the numerous crinoideans of the palæozoic ages, but five or six specimens have been brought to Europe.† It belongs to that subdivision in which the joints of the column are pentagonal, hence its generic name.‡

38. STRUCTURE OF THE CRINOIDEA.—From this recent example (*Lign.* 151), which does not essentially differ from

* The living British Star-fishes are beautifully figured in the late Professor E. Forbes's charming work, published by Van Voorst, 1841.

† Petrifactions and their *Teachings*, p. 77. ‡ Medals, p. 282.

the extinct forms, a more accurate knowledge of the structure of these curious animals has been obtained. The Crinoideans are characterized by having a root or process o attachment, by which they are fixed at the base to the rock

LIGN. 151.—THE BODY AND UPPER PART OF THE STEM OF PENTACRINUS CAPUT-MEDUSÆ.*
(From the West Indian Seas.)

—a stem composed of numerous articulations, or separat pieces of a solid calcareous substance,—and a cup or vase a the summit of the stem, which contains the body or viscera of the animal, and from the upper border of which procee articulated arms or tentacula. When the animal is aliv

* *First* figured and described by M. Guettard; see Parkinson, Or *Rem. vol. ii. p.* 266; and Müller, *op. cit.* p. 185.

the skeleton is covered by a soft integument, as in the Star-fishes; the mouth is situated on one side of the centre of the receptacle, which is surrounded by the arms that spread out and expand into a net to capture the living prey, and, like the tentacula of the hydra, seize and convey it to the mouth. I scarcely need remark that the Crinoidea are individual organisms, and are never aggregated and united by one common axis, as are the compound Polypifera that lately engaged our attention. There are some fossil crinoideans destitute of a stem, and these must have been free animals,

LIGN. 152.—STEMS OF ENCRINITES AND PENTACRINITES.

Fig. 1. Screw- or Pulley-stone; a cast in the hollow of an encrinital column.
2, 4. Articulating surfaces of different kinds of encrinital ossicula, or Trochites.
3, 5. Portions of encrinital stems, or Entrochi. 6, 8, 10. Stems of Pentacrinites.
7, 9. Separate ossicula, or Trochites, of Pentacrinites.

floating at liberty through the water, like their analogues, the recent Feather-stars.

The number of ossicula in the skeleton of a single Encrinite has been *computed at thirty* thousand; but in the more complicated Pentacrinites they exceed one hundred and fifty thousand, and in the plumose species must amount to hundreds of thousands.* The detached ossicula occur in myriads in the Carboniferous, Devonian, and Silurian rocks, and the relics of one species alone sometimes form thick beds of marble in the mountain-limestone series.

39. Encrinites and Pentacrinites.—The fossil remains of Crinoidea consist of the ossicula of the column, arms, and tentacula,—of the plates of the vase or receptacle,—and of the more massive peduncle, by which the base of the column was permanently fixed to the rock. The separate bones of the column were called *trochites*, or wheel-stones, by the early collectors; and several united, *entrochites*. In the north of England they were popularly known by the name of "fairy-stones," and "St. Cuthbert's beads:"† the circular perforated kinds are occasionally found in tumuli, having been worn as ornaments by the ancient Britons. These bodies present considerable variety in form, and their articulating surfaces are marked with diversified floriform and stellular figures; as in the series of specimens before us (*Lign.* 152). The central perforation, which is circular and very small in some species, and large and pentagonal in others, forms in the united-column a channel from the receptacle to the base, which is supposed to have contained a chord of animal matter. The inner part of the ossicula seems to have been more perishable than the external zone; for the former is often filled up either with spar, or the material of the surrounding rocks. In the silicious veins and bands of chert that pervade some of the limestones of Derbyshire, the curious fossils termed "pulley-

* The ossicula of an Extracrinus are calculated, at a moderate computation, to amount to the number of nearly 750,000. Austin's *Monog. Crinoid.* p. 105.

† *Parkinson* (Org. Rem. vol. ii. p. 155, &c.) enumerates the popular *names by which* these little fossils have been known in different countries.

stones," or "screw-stones," often occur; these are casts formed by the infiltration of silex into the cavities of encrinital columns (*Lign.* 152, *fig.* 1).

1

2

LIGN. 153.—ENCRINITAL MARBLE OF YORKSHIRE.*

Fig. 1. Entrochites, or fragments of stems of Encrinites (*Rhodocrinus verus?*), lying in relief on a weathered block of limestone; from Garsdale, West Riding, Yorkshire.

2. Polished slab of the same encrinital marble, showing the portions of stems cut at various angles.

Occasionally encrinital joints are found in the fluor-spar

* For the Fossil Zoophytes and Crinoids of Yorkshire, see Prof. J. Phillips's "*Geology of Yorkshire,*" especially vol. ii. plates 1, 2, and 3.

contained in the mountain-limestone of Derbyshire;* and thus show that this beautiful spar has been the result of some metamorphic action on the limestone, the organic remains alone resisting the transmuting influence of the fluoric acid.

The skeletons of the Crinoidea, like the stony fabric of the corals, were, of course, secreted by the animal membrane; and, as in the fossil coral (p. 654), this tissue may be detected. Upon submitting some encrinital ossicula from the Derbyshire limestones to the action of weak acid, the calcareous earth was removed, and the original membrane appeared in transparent flocculi.†

40. Derbyshire encrinital Marble.—Some of the strata of Mountain-limestone, both in Europe, Asia, and America, consist entirely of remains of Crinoidea; and in Derbyshire some of the beds form a compact marble, which is largely employed for chimney-pieces and other ornamental purposes.

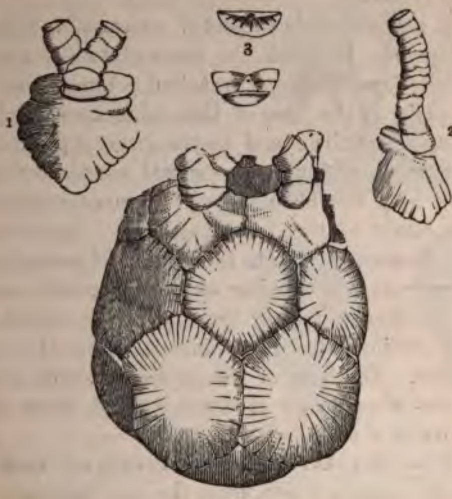
In the quarries on Middleton Moor, a short distance from Cromford, in Derbyshire, extensive quarries of this marble are worked, and abundance of these fossils are everywhere scattered about. The cavities of the entrochites are often filled with white calcareous spar, while the ground of the marble is of a dark reddish brown. In other varieties the substance of the fossils is white, and the ground dark-grey or brown: both kinds, when worked into polished slabs or ornaments, are very beautiful and interesting. A specimen of such limestone (from the borders of Westmoreland and Yorkshire), with the crinoidal columns in relief, is represented, *Lign.* 153, *fig.* 1, and a polished slab in *fig.* 2.

41. The Lily-Encrinite.—One of the most elegant of the fossil crinoidea is the *Lily Encrinite* (*Encrinus liliiformis*, *Schlotheim*), which, as already stated, occurs only in the

* *Quart.* Journ. Geol. Soc. vol. vii. part 2, Miscell. p. 115.

† *See* Parkinson's Organic Remains, vol. ii. p. 166.

Muschelkalk of the Triassic system of Germany (p. 550), and is principally found in one locality, near the village of Erkerode, in Brunswick. The structure of this animal is beautifully exemplified in the fine specimen figured in *Lign.* 131, which was formerly in the collection of Mr. Parkinson *



LIGN. 154.—MARSUPITE † FROM THE CHALK, NEAR ARUNDEL.

(Collected and drawn by G. A. Coombe, Esq.)

Fig. 1. A plate with the base of one of the arms attached. 2. Lateral view of one of the arms. 3. The Ossicula, by which the arms are attached to the body. 4. The Marsupite, with the first five ossicula of two of the arms attached to the brim of the pelvis.

The stem of the *Encrinus liliiformis* is constructed of ossicula alternately large and orbicular, and small and

* Org. Rem. vol. ii. pl. XIV. p. 174.

† This is probably the *Marsupites lævigatus* of Forbes, *Dixon's Foss. Sussex*, pl. 20, fig. 8. The species of this genus have not, however, been yet well worked out. Remains of Marsupites have been found in the chalk of Kent (Margate), Sussex (Offham, Preston, Brighton, and Burpham, near *Arundel), Wilts (Tidworth)*, and Danes Dike, Yorkshire.

cylindrical, thus forming a column of great flexibility. The "pelvis," or plated cup containing the body, resembles in shape a depressed vase; the upper part of its cavity appears to have been closed by an integument protected by numerous plates, the mouth of the animal being situated near the centre.

It will elucidate this subject if we examine this specimen of a *Marsupite*, in which the bases of two of the arms are preserved (*Lign.* 154). A vertebral column attached to the central plate, at the base of this crinoidean, would convert it into an Encrinite; and in the large expanded plates of the receptacle, and the strong and simple ossicula of the arms, we have the elements of the more complicated and delicate fabric of the Lily Encrinite. In another specimen of Marsupite (now in the British Museum), the plates which covered the opening of the receptacle are preserved.* The Marsupite may therefore be considered as a free Crinoid, uniting the Comatulidæ with the Apiocrinidæ and their allies. The form of the perfect skeleton of the Marsupite was shown in a previous lecture, when treating of the Radiaria of the Chalk (p. 337).

42. Pear-Encrinite (Apiocrinus) of Bradford.†—A smooth Crinoid, which, from the body having a pyriform shape, has received the name of Pear-Encrinite, occurs in considerable numbers in the Oolite near Bradford in Wiltshire, under the interesting circumstances already mentioned (p. 504).

The receptacle or body-cup of this Encrinite is very smooth, and crossed transversely by fine lines where the plates of which it is composed unite. The stem is short, smooth, and strong; the arms are simple, and bear considerable resemblance to those of the Marsupite. In this drawing (*Lign.* 155, *fig.* 1), reduced from Mr. Miller's work on

* See Fossils of the South Downs, pl. XVI. fig. 6.

† *Medals of* Creation, p. 289; Pictor. Atlas, pl. L. figs. 1—8.

the Crinoidea, a group of these animals is represented as if alive in the water. A few perfect specimens have been obtained; but the body is usually found deprived of the arms, and broken off at the top of the column (*fig.* 2): the vertical polished section (*fig.* 3) shows the form and arrangement of the plates composing the receptacle or pelvis.

1 2 3

LIGN. 155.—PEAR-ENCRINITE OF BRADFORD.

(*Apiocrinus Parkinsoni.*)

Fig 1. A group of Apiocrinites represented as alive in the water; some with the tentacula expanded, others closed.
2. Body of the Pear-Encrinite.
3. A vertical section of the same.

There is a crinoidal genus, termed *Bourgueticrinus* by D'Orbigny,* much resembling the *Apiocrinus* in miniature, and formerly confounded under the same name, that occurs plentifully in the Chalk of England and Europe, and has been found also in the London Clay. Parts of two species are figured in the *Medals*, vol. i. p. 291, *Lign.* 93.

43. PENTACRINITES, ACTINOCRINITES, &c.†—In the Pentacrinus and closely allied Extracrinus,‡ the ossicula composing the columns are pentagonal, but in some species they have only four angles (*Lign.* 152, *fig.* 10); and in some the angles are acute, in others rounded. The stems are furnished with numerous side-arms (see the recent speci-

* Hist. Nat. Crinoides, 4to (unfinished).
† Medals, p. 294, *Lign.* 94: Buckland's Bridg. Treat. pl. 47—53.
‡ See the unfinished *Monograph on* Recent and Fossil Crinoidea, by Messrs. *Austin, p. 95, &c.*

men, *Lign.* 151), and the tentacula subdivide into innumerable branches, which terminate in delicate articulated rays.

LIGN. 156.—CRINOIDEA FROM THE MOUNTAIN-LIMESTONE AND SILURIAN FORMATIONS.

Fig. 1. *Cyathocrinites pyriformis*, from the Wenlock limestone. (*Murchison's Silurian System.* Pl. 17, fig. 6.)

2. Restored figure of *Actinocrinus triacontadactylus* from the Mountain-limestone. (*Miller's Crinoidea*, p. 96.) *a*, the root-like processes of attachment; *b*, the side-arms; *c*, the pelvis; *d*, the arms or tentacula.

Allusion has already been made (p. 528) to the abundance and extreme beauty of the plumose Pentacrinites of the Lias-shale at Lyme Regis, and other localities in Yorkshire, Gloucestershire, and Somersetshire. See also *Lign.* 157.

Many other genera of this numerous family have been discovered, and are figured and described by palæontologists.* In some instances the receptacle appears to be

* *For a more* particular account of the natural history of this tribe of

closed, the tentacula being retracted or bent inwards, as if the animal had been in the act of conveying prey to its

LIGN. 157.—PENTACRINITES SUBANGULARIS.*
In Lias Limestone, from Boll, Wirtemberg (one-sixth nat. size).

mouth, at the very moment of its becoming enveloped in its rocky sepulchre (*Lign.* 156, *fig.* 1). In other exam-

animals, besides the works by Parkinson, Miller, D'Orbigny, Austin, Phillips, and others, already referred to, see Forbes, Memoirs Geol. Survey, vol. ii., and Monog. Tert. Echin. (Pal. Soc.); Goldfuss, Petrif. Germaniæ, &c.; M'Coy, Palæoz. Foss. Cambridge Mus.; Hall, Palæont. New York; and especially the masterly history of the Crinoids of the Carboniferous System, by MM. L. de Koninck and H. le Hon (Mém. Acad. Roy. Belgique, 1854), which contains a remarkable register of nearly 350 books and memoirs, dating from 1558 to 1853, in which these interesting fossils have been described. Since 1853 Rœmer, Müller, Sandberger, Shumard, Wright, and others have added much to our knowledge of the Crinoids. Bronn's New Edition of his *Lethæa Geognostica*, and Pictet's *Paléontologie*, 2nd Edit. vol. iv., should be consulted for the latest résumés on the subject: these two works supply also beautiful series of illustrations of all the *generic forms* of this family.

* This *is a portion of a beautiful* specimen in the British Museum.

ples, the skeleton lies in relief, with the arms spread out, as if the creature, while floating at its ease in the water, had been suddenly surrounded and entombed in the mud (*Ligns.* 157, 158). The elegant plumose encrinite, termed *Actinocrinus*,* occurs in a beautiful state of preservation in the Mountain-limestone; the form of the original is well represented in the *Lign.* 156, *fig.* 2, p. 664. The receptacle of the Actinocrinite is constructed of numerous plates, which in many species are richly ornamented; and some have the surface granulated in a radiating manner, like those of certain varieties of the Marsupite. In another genus, the *Cyathocrinus* (*Lign.* 158), the receptacle is very simple, and composed of but few plates. The ossicula of the columns in the Actinocrinites and Cyathocrinites are round and smooth: a beautiful specimen of the cup-shaped Encrinite is represented, of half the natural size, in *Lign.* 158.

Lign. 158.—Cup-like Encrinite.
(*Cyathocrinites planus.*)
From the Mountain-limestone, Clevedon, Somersetshire

44. Pentremites and Cystidea.—The species and even genera of the fossil Crinoidea† are so numerous, that their bare enumeration would require more space than we can allot to the subject, and I can only notice two other remarkable types.

* *Signifying* the Radiated, or Nave-and-spoke Lily-animal.

† *M. Pictet* enumerates upwards of a hundred genera.

Pentremites. These Lily-shaped animals seem to hold an intermediate space between the Echinites and the Encrinites. Their receptacle consists of five petaloid divisions united by corresponding series of plates, which meet in a point at the summit. Each petal is divided by a groove, and is perforated near the apex. They have a very short pedicle. These Crinoideans are so abundant in some of the cherty beds of the mountain-limestones of Kentucky,* that the rocks have acquired the name of Pentremital limestone. Six or seven species occur in the mountain-limestone of Yorkshire.

Cystidea. In the oldest of the fossiliferous strata there occur certain Crinoideans of a type which is supposed to be restricted to the older palæozoic periods. There are about fifteen species in Britain, chiefly of the genera *Echinosphærites* and *Pseudocrinites*. These fossils were distinguished by Von Buch † by the name of *Cystidea*. The receptacle is of an oval form, composed of numerous polygonal plates articulated together, and having the necessary apertures on the side of the cup required by the economy of the animal; it has a short pedicle. The Cystidea are supposed to be destitute of true arms. They comprise several genera, and are among the first forms in which the Crinoidea appear in the natural records of our planet.

I must here conclude this very general notice of the Crinoideans, a family which, though of excessive rarity in the present seas, swarmed in the oceans of the earlier epochs, in various modifications of form and structure, comprising numerous genera and species, all of which are now extinct.

45. Concluding remarks. — From this review of the Polypifera and Crinoidea, we learn that an atom of living jelly floating in the ocean, and at length becoming affixed

* Say; Journal of the Acad. Nat. Sciences of Philadelphia, for 1820.

† Transact. Acad. Berlin; and Quart. Journ. Geol. Soc. vol. ii. part 2, Miscell. p. 20; and *Austin, ibid.* vol. iv. p. 291.

to a rock, may be the first link in a chain of events, which after the lapse of ages may produce important modifications in the physical geography of our globe. We have seen that the living polypes in their rocky habitations enjoy all the blessings of existence, and at the same time are the unconscious instruments of stupendous operations, which in after-ages may affect the destinies of mighty nations; and that the materials elaborated by their agency, and subsequently consolidated by chemical changes, may become the foundations of Islands and Continents, and constitute new and favourable sites for the abode of future generations of the human race.

And when we bring the knowledge thus acquired to bear on the natural records of our planet, and examine the rocks and mountains around us, we find that in periods so remote as to exceed our powers of calculation, similar effects were produced by beings of the same type of organization as those whose labours have been the subject of our contemplation. We are thus enabled to read the history of the past, and to trace the succession of events, each of such duration as to defy all attempts to determine with any approach to probability the period required for its development.

In fine, these investigations have shown us the marvellous structure of creatures invisible to the naked eye, their modes of life and action, and the important changes effected in the relative proportion of land and water, by such apparently inadequate agents. They have instructed us, that above, beneath, and around us there are beings so minute as to elude our unassisted vision, yet possessing sensation and voluntary motion, and each furnished with its systems of nerves, muscles, and vessels, and preying upon creatures still more minute, and of which millions might be contained in a drop of water; nay, even that these last are supported *by living* atoms still less, and so on—and on—until the *mind is lost* in astonishment, and can pursue the subject no

Thus are we taught,—

"That those living things
To whom the fragile blade of grass,
That springeth in the morn
And perisheth ere noon,
Is an unbounded world—
That those viewless beings,
Whose mansion is the smallest particle
Of the impassive atmosphere,
Enjoy and live like man!
And the minutest throb,
Which through their frame diffuses
The slightest, faintest motion,
Is fixed and indispensable
As the majestic laws
That rule yon rolling orbs!"

SHELLEY.

We have contemplated the results produced by these countless myriads of animated forms,—the excess of calcareous matter brought into the waters of the ocean consolidated by their influence, and giving birth to new regions; and we have obtained evidence that in the earlier ages of our globe, like effects were produced by similar living instruments. The beds of fossil coral are now the sites of towns and cities, whose inhabitants construct their abodes of the limestones, and ornament their temples and palaces with marbles formed of the petrified skeletons of the zoophytes which lived and died in oceans that have long since passed away!

Hence we perceive that He who formed the Universe creates nothing in vain; that His works all harmonize to blessings unbounded by the mightiest or the most minute of His creatures; and that the more our knowledge is increased, and our powers of observation are enlarged, the more exalted will be our conception of His wondrous works!

LECTURE VII.

THE CARBONIFEROUS SERIES.

1. Introductory. 2. The Carboniferous Series. 3. The Coal-measures. 4. Coal-field of Derbyshire. 5. Coalbrook Dale. 6. Nature of Coal-deposits. 7. Mode of Deposition of the Coal-measures. 8. The Great Dismal Swamp of Virginia. 9. Erect Trees in the Carboniferous Deposits. 10. Upright Trees at Wolverhampton and St. Etienne. 11. Upright Trees in the Coal-measures of Nova-Scotia and Cape Breton. 12. Coal-shales and Vegetable Remains. 13. Millstone Grit. 14. Carboniferous Limestone. 15. Derbyshire Lead-mines. 16. Carboniferous Rocks of Devonshire. 17. Trap-rocks and Trap-dikes of the Carboniferous Series. 18. Faults in the Coal-measures. 19. Geographical distribution of the Carboniferous Strata. 20. Carboniferous Rocks of North America. 21. Organic remains of the Carboniferous Series. 22. Organization of Vegetables. 23. Climate and Seasons indicated by Fossil Wood. 24. Microscopical examination of Fossil Trees. 25. Nature of Coal. 26. Liebig on the formation of Coal. 27. Bitumen, Petroleum, and Naphtha. 28. The Diamond. 29. Anthracite, Plumbago, &c. 30. Petrifaction of Vegetables. 31. Artificial Vegetable Petrifactions. 32. Silicification of Vegetables. 33. Fossil Plants of the Coal. 34. Equiscetaceous Plants. 35. Fossil Ferns. 36. Sigillaria. 37. Stigmaria. 38. Lepidodendron. 39. Coniferous Trees and Plants. 40. Flora of the Coal. 41. Atmospheric conditions during the Carboniferous period. 42. Formation of Coal-measures. 43. Coal-measures originating in submerged Lands. 44. Zoophytes and Echinoderms of the Carboniferous Series. 45. Shells of the Carboniferous Series. 46. Crustaceans and Insects. 47. Fishes of the Carboniferous Series. 48. Reptiles of the Carboniferous period. 49. Climate of the Palæozoic Ages. 50. Retrospect, and Botanical Epochs.

1. INTRODUCTORY.—From the contemplation of the changes produced on the earth's surface by the agency of minute beings whose nature and economy are known only to the instructed observer, we resume the geological argument from which we have for a while digressed, and enter upon the examination of the series of strata deposited during the period immediately antecedent to the Permian formation described in the fifth Lecture.

The *Carboniferous series*, so named from its comprising the principal deposits of mineral fuel, consists, in England, of a *great triple* formation of, 1st (lowest), a group of calcareous strata, locally interbedded with shales, sandstones, ironstone, and coaly beds (Mountain-limestone); 2nd, a group of gritty and sandy beds, also with some coal (Millstone-grit); 3rd, an argillaceous and sandy group, with little limestone, but much ironstone and bituminous shale, and with numerous intercalated seams and thick beds of the carbonized vegetable matter termed Coal.* Independently of the interest attached to these deposits from the immense accumulation of fossil plants of which many of them are wholly composed, this series involves the consideration of some very remarkable geological phenomena; for the manner in which such extensive layers of carbonized vegetable substances (like the intercalated masses of rock-salt in the red marls of the Trias, p. 541), unmixed with extraneous matter, were produced, is a problem difficult of solution, under certain conditions in which it is presented to our examination. The deposition of coal appears, as we shall presently show, to have taken place under various circumstances; the coal being in some cases associated with fresh-water, and in others with marine organic remains.

But, though from the vast importance of mineral fuel in an economical point of view to nations in an advanced state of civilization, and the botanical interest with which such extensive natural herbaria of the palæozoic ages are invested, the coal is generally regarded as constituting the essential feature of this epoch, yet it would be more philosophical to consider these intercalations of carbonized vegetables, like beds of shells, &c., as extraneous and accidental. We have already seen, that the formation of coal was not

* In the Crystal Palace Gardens has been constructed a section of the coal-measures, the natural rocks being used as the constituents. In Germany, Dr. Beinert has formed, in his beautiful gardens at Charlottenbrunn, a highly interesting artificial section of the coal-beds, with fine specimens of the fossil plants in place; and Prof. Goeppert has erected a still larger *section in the Royal* Botanic Gardens at Breslau. See H. R. *Goeppert's Der Königl. Botan.* Garten der Univ. Breslau, 8vo, 1857.

confined to the carboniferous system;* but that beds of this substance (under the various forms of peat, brown-coal, lignite, jet, pitch-coal, cannel-coal, bituminous shale, slate-coal, anthracite, glance-coal, and common coal) have been and will be produced, wherever trees and plants are accumulated in sufficient quantity and under the requisite conditions.

The peculiar types of vegetable organization comprised in the flora of this period afford the only distinguishing characters of the beds of coal interpolated in the strata that were deposited during the ages intervening between the close of the Devonian epoch and the commencement of the Permian.†

The strata comprised in the Carboniferous series form two natural groups, as shown in the following table; and I propose to consider, in the first place, the general features of the deposits, and their geographical distribution; secondly, the nature and formation of coal, and the characters of the fossil plants of which it is composed; and, lastly, to notice the animal remains, and take a retrospective view of the successive floras which have prevailed on the surface of the earth during the periods embraced by our geological investigations.

2. THE CARBONIFEROUS SERIES.—Though in England simply divisible into a threefold series of calcareous, aren-

* See Dr. F. Senft's "Classification and Beschreibung der Felsarten," 8vo, 1857: also Dr. Geinitz's "Steinkohlen-Formation in Sachsen," fol. 1856. A resume of the latter of these valuable works is given by Col. Portlock in his Presidential Address to the Geological Society in 1857 (p. cxxv.). See also Sir R. Murchison's "Siluria."

† See remarks on the Coal of the Oolite, p. 513; of the Wealden, p. 405; of the Tertiary, p. 283; and in peat, p. 66. It should be remembered that coal occurs also in the Cretaceous Series (in Saxony and elsewhere), in the Oolitic and Liassic series (at Boll in Wirtemberg, at Seefeld in the Tyrol, and at Walgau in Bavaria, and in Banat, &c.), in the *Triassic* series of Germany, and in the Permian series of Saxony; also *occasionally* in the Devonian series: nor are the Silurian and Cambrian, and even the hypogene rocks, without their carbonaceous contents.

aceous, and argillaceous beds, the carboniferous system, even in the British Islands, becomes far more complicated in the details of its stratification. In Ireland it commences with an important division, comprising sandy and shaly beds "(Yellow Sandstone" * and "Carboniferous Slate," of Griffith), 2000 feet thick; and the limestone itself (5000 feet thick) is there separable into three great divisions. In the western counties of England, and in South Wales, these lowest sandstones, shales, and thin limestones are represented by from 100 to nearly 600 feet of laminated beds, with marine shells, fishes, and terrestrial plants; and in Fifeshire there is a thickness of 1500 feet of equivalent beds. In its extension northward of Derbyshire the Mountain- or Scar-limestone becomes more and more interstratified, in its higher portion, with shaly beds; and in the northern counties and in Scotland the great bulk of this characteristic limestone-formation is not only replaced by clays, sands, and calcareous shales, but these are intercalated with numerous coal-beds, often of considerable thickness; thus forming an important series of lower coal-measures, the representatives of which exist also in Europe and in Nova Scotia. The following tabular arrangement exhibits the lithological characters and relations of the carboniferous deposits.

* Brit. Assoc. Report, 1852, Sect. p. 43. The "Yellow Sandstone" is correlated by Godwin-Austen (Geol. Quart. Journ. vol. ix. p. 244) with the Pilton and Petherwin beds of North Devon, and referred by him, with the Yellow Sandstones of the Boulonnais and the Cypridina-schists of Germany, to the Upper Devonian. To this member of the Palæozoic series Sedgwick has also provisionally referred it (Phil. Mag. 1854, vol. viii. p. 364, and Geol. Journ. vol. viii. p. 8). Dr. Sharpe, however, inclined to the collocation of the Petherwin group with the Carboniferous system (Geol. Quart. Journ. vol. ix. p. 247). It may therefore be said of these beds of passage from the Devonian to the Carboniferous system, as of the transitional beds between the Silurian and Devonian, the Carboniferous and Permian, the Trias and Lias, the Lias and Oolite, &c., that much exact observation has still to be made in these and other *closely related instances.*

CARBONIFEROUS SYSTEM.

UPPER. (Upper coal-measures.)

1. COAL-MEASURES;—divisible * into Upper, Middle, and Lower (or "Ganister") series. Grit, sandstone, and shale or clay, with numerous beds of coal; ironstone, in nodules and irregularly stratified; and occasional intercalations of limestone-bands. Fossil reptiles and fishes; molluscs (chiefly freshwater), annelids, insects, and crustaceans are not uncommon in some parts. Thickness upwards of 4000 feet in some districts of England.
2. MILLSTONE-GRIT.—Coarse quartzose sandstone, passing into grit and conglomerate, used for millstones (hence the geological term), with shales and sandstones; containing the trails of molluscs and annelids, rare traces of reptiles, and interspersions of fossil plants and vegetable matter, and sometimes layers of coal. Thickness about 800 feet.

LOWER. (Lower coal-measures, or the mountain-limestone group.)

3. UPPER LIMESTONE-SHALES or YOREDALE ROCKS.—Alternations of limestones, shales, and sandstones; with some chert, rotten-stone, ironstone, bitumen, and coal; marine shells (*Goniatites*, *Orthoceras*, *Productus*, and *Posidonomya; Encrinites*, &c.): thickness about 500 feet.
4. MOUNTAIN-LIMESTONE or SCAR-LIMESTONE.—A series, upwards of 1000 feet in thickness, of massive limestones, shales, and flagstones, with dolomite, bitumen, rotten-stone, chert, galena, and iron-ore; corals, crinoids, and marine shells in profusion, and some trilobites. Beds of marble wholly made up of petrified zoophytes or of crinoids. This group is devoid of coal in South-western and Central England; but the mountain-limestone of Westmoreland, Northumberland, Fifeshire, and some parts of Europe and North America, contains extensive coal-beds, with occasional tracks of reptiles.

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* In the southern coal-fields two divisions only are apparent: Murchison's "Silurian System," chap. 6.

5. Lower Limestone-shale. — Alternating shales, sandstones, and limestones; with posidonomya, orthis, and spirifer; abundance of fish-remains, coprolites, and cypridæ; and some remains of plants. About 400 feet thick.

3. The Coal-measures. — The bituminous substance termed coal is simply vegetable matter altered by chemical changes, which will hereafter be considered. It occurs in beds that vary from a few inches to a fathom or more in thickness, and are interposed between strata of shale, clay, micaceous sandstone, limestone, and ironstone; alternations of this kind, occupying circumscribed areas, are termed *coal-basins*. Mr. Bakewell observes that the strata thus disposed may be imitated by a series of mussel-shells or saucers placed one within the other, and having layers of clay interposed. If one side of the series be raised to indicate the general rise of the strata in that direction, and the whole be dislocated by cracks, the general arrangement of the beds and the displacements which they have undergone will be represented; each shell representing a bed of coal, and the partitions of clay imitating the earthy strata which separate the carbonaceous layers.

It is the association of iron-ore with the limestone that serves as a flux, and with the mineral fuel required for the reduction of the ore into a metallic state, that has given rise to the numerous iron-foundries established over the sites of our principal coal-fields. The usual characters of a *Coal-field*, as a series of strata of this kind is termed, are shown in the section of that of South Gloucestershire (*Lign.* 124, p. 522). Here we perceive that the Devonian or Old Red Sandstone has been elevated into a position almost vertical, and that the *Mountain-limestone*, which lies immediately upon it, partakes of the same inclination. This is succeeded by conformable beds of *Millstone-grit*, which are followed by alternations of Coal and shales; the *Permian* and Triassic *beds*, the *Lias*, and *Inferior Oolite* (3, 4, and 5) are seen above in an unconformable position. The *Mountain-limestone* and *Millstone-grit* (1, 2) also appear on the opposite flank of the elevated ridge of the Mendips. The chronological order of the deposits exhibited in this section, that is, the succession according to their original position before they had suffered displacement, is as follows: immediately overlying the lowermost or most ancient, the Devonian strata of the Mendip Hills, we have — 1. Mountain-limestone.—2. Millstone-grit; upon this are alternations of Coal, shale, and grit.—3. Permian and New Red Sandstones. —4. Lias.—5. Inferior Oolite.—6. Great Oolite.—7. Oxford Clay, south of Malmesbury.

The term *basin*, applied to these accumulations of carboniferous strata, must be taken in a general sense; for, though some of these groups of deposits may have been formed in circumscribed depressions, it is evident that, in general, the beds have originally extended over large areas, and that their present isolated position and confined limits are attributable to subsequent elevations and depressions by which the "faults" or dislocations of the coal and associated strata of the rocks on which they repose have been produced. Extensive denudations have completed the separation of the coal-basins.

Of the English coal-fields, those of Newcastle, Durham, Yorkshire, Lancashire, Flintshire, Cheshire, Derby, Nottinghamshire, Leicestershire, and Warwickshire have many features in common; those of South Staffordshire and Worcestershire are related more nearly to each other than to the other coal-fields; and those of Glamorganshire, Monmouthshire, Gloucestershire, and Somerset form another allied group.* The coal-measures of the northern counties are divisible into a triple series—upper, middle, and lower; the last, also known as the "Ganister series," contains in Yorkshire a single shale-bed of marine origin, with *Goniatites*, *Posidonomyæ*, and fishes. Other instances of the irruption of sea-waters into the generally fresh-water area of the coal-measures,—the last efforts, as it were, of the old carboniferous ocean to regain possession of the

* Phillips' "Manual of Geology," 1855. Both this valuable elementary work and Prof. Ansted's "Elementary Course of Geology," 1856, contain particulars of the relative extent of the English coal-fields, and of the thickness and character of their respective coal-beds.

rapidly shallowing region,—are evidenced by occasional marine deposits in the coal-fields of Lancashire, Dudley, and Coalbrook-dale.

4. Coal-field of Derbyshire.—The Derbyshire Coal-field will serve as a type of the English series.

The strata of Carboniferous Limestone which form the grand mountain-chains of Derbyshire decline towards the eastern side of the county, and sink beneath the Coal-measures. Immediately upon the limestone are beds of calcareous slate or shale, about four or five feet in thickness (known as the "Limestone-shale," and equivalent to the Yoredale rocks of Yorkshire), intercalated with grit-stones, and about four or five hundred feet in thickness. This series of alternating beds, compact and soft, coarse and fine, many of which readily disintegrate from weather-action, forms the exposed face of Mam Tor, or the "*shivering mountain*," near Castleton. They are succeeded by a mass of grit, or conglomerate, with vegetable remains, which is worked for mill-stones. Above the Millstone-grit are the regular Coal-strata, comprising sandstones of various qualities, and often in exceedingly thin laminæ,—indurated clay-beds,—iron-stones, the nodules of which contain organic remains,—and softer argillaceous beds, which, being of a slaty structure, are called *shales*. Two of the layers of clay, termed *mussel-bind*, abound in bivalve shells, somewhat resembling fresh-water mussel-shells, but of extinct types of forms. The total thickness is 1310 yards, which includes thirty different beds of coal, varying from six inches to eleven feet, and making the amount of coal about twenty-six yards. In the shales below the coal there is a transition from calcareous strata, with marine animal remains, to fresh-water mud-deposits, with terrestrial vegetables: this may have originated from occasional intrusions of freshets from a river.

The series above enumerated is often repeated; shales, clays, and sandstones occurring under different beds of coal, with a great similarity in the succession and thickness of each. Interruptions to the continuity of the beds, from cracks and fissures which have taken place since the original deposition of the strata, are everywhere apparent. Dikes or intrusions of extraneous mineral matter are of frequent occurrence, separating the strata by vertical walls, which are from a few inches to many yards in thickness. These extraneous masses sometimes consist of indurated clay, but more commonly of the ancient volcanic rock termed *basalt* or *trap*.

5. Coalbrook Dale.—In Shropshire the carboniferous strata are exposed over several detached areas.*

* *Consult Sir R. I. Murchison's* admirable description of the *Carboniferous System; "Silurian* System," chap. vi.

Near Shrewsbury the coal-beds are associated with limestone, of fresh-water or estuary origin, and containing minute entomostraca (*Cypridæ*), annelids (*Serpulæ*),* shells (related apparently to *Modiola* and *Unio*),† and fishes. But the most important and productive carboniferous tract in Shropshire is *Coalbrook Dale*, which is situated on the east side of the range of rocks forming the Wrekin and Wenlock Edge, the coal-strata being superposed on mountain-limestone; it contains beds and nodules of iron-stone, enclosing organic remains. This coal-field ‡ is remarkable for the dislocated and shattered condition of the strata, and the intrusion of volcanic rocks; the latter do not appear as dikes or veins, in the fissures of the beds, but rise up in mounds or protuberances. The walls of the fissures are in some instances several yards apart, the intervals being filled with debris. Strata containing marine shells alternate with others abounding in fresh-water shells and land-plants, as in Derbyshire. These alternations prove that these coal-measures were deposited in an estuary, subject to occasional freshets from a considerable river; the frequent alternations of coarse sandstones and conglomerates with beds of clay and shale, containing the remains of the plants brought down by the river, support this opinion. The strata forming this carboniferous series consist of quartzose sandstone, indurated clay, slate-clay, and coal. A pit sunk in Madely colliery, to a depth of 730 feet, passed through eighty-six beds of alternating quartzose sandstone, claystone porphyry, coal, and indurated clay containing nodules of argillaceous ironstone. The sand-

* These little *Serpulæ* have been described as planorboid molluscs, under the name of *Microconchus*; but there is no doubt of their being true Serpulæ, as pointed out by Mr. E. W. Binney (Memoirs Phil. Soc. Manchester, vol. x. p. 196). They are frequently attached to vegetable fragments. In Nova Scotia these little annelids occur plentifully under the same conditions; indicating in some instances the drifting of plants in sea-water, and in others the advance of estuarine waters over submerged jungles. A similar form is found on the fossil plants of the Mountain-limestone of Northumberland (G. Tate, Flora M. L. pl. xiii. fig. 6), and on the marine shells in the coal-measures of Coalbrook Dale (Geol. Trans. 2nd ser. vol. v. pl. 40, figs. 1, 3, 5), and also attached to the fossil shells and corals in the Devonian rocks of Russia and the Eifel (*Spirorbis omphalodes*, Goldfuss).

† Probably *Myalina* and *Anthracosia*, of King. Such as these occur also in the coal-measures at the Joggins in Nova Scotia, Quart. Journ. *Geol. Soc.* vol. x. p. 12 and p. 39, figs. 22—25.

‡ *See a highly* interesting memoir on this coal-field, by Mr. Prest-wich, *Geol. Transact.* 2nd ser. vol. v. p. 413; also Murchison's "Silurian System," chap. vii.

stones of Coalbrook Dale are fine-grained and micaceous; and some beds are penetrated by *petroleum*, which at Coalport escapes from the surface in a tar-spring; bitumen also occurs in some of the shales. Plants, shells, and crustaceans * are abundant in the shale and iron-stone nodules; and the remains of insects are sometimes met with.†

6. NATURE OF COAL-DEPOSITS.—This brief notice of two of the British coal-fields will serve to convey a general idea of the strata of which a coal-basin consists.‡ But it is necessary to enter more particularly on the nature and arrangement of the beds of coal, and their associated deposits; for, though many accumulations of carboniferous rocks have manifestly been formed by different and local agencies, the grand series of ancient coal-measures, setting aside unimportant discrepancies, present a remarkable uniformity of character, not only throughout Great Britain and Europe, but also in most other parts of the world.§

* Both Cypridiform and Limulus-like Entomostracans. Prestwich, *loc. cit.* pl. 41.

† Medals of Creation, vol. ii. p. 554.

‡ In a little anonymous work, entitled "Our Coal and Our Coal-pits," published in 1853 (Longman), the reader will find a vast deal of good information about coal-seams and coal-pits, such as certainly has not been brought together in any other work, but which is of interest and value both to the geological and the general student.

§ The various Memoirs on the British Coal-fields in the Geological Society's Transactions and Journal, in the Reports of the British Association, and in the Transactions of the Northumberland, Manchester, and other Societies, by some of our most eminent observers; and in the works of Lindley and Hutton, Holmes, Mammatt, Mushet, D. Milne, Hibbert, Bakewell, Conybeare, Ansted, Phillips, Lyell, De la Beche, Buckland, Murchison, and others, will afford those who wish to pursue the inquiry, information of the most important and interesting nature. The Coal-fields of Ireland have been described by Weaver, Griffith, and Portlock. "The Annales des Mines" and "Bulletin Soc. Géol. France" are rich with notices of the Belgian and French coals; and Godwin-Austen and Sharpe have also treated of the Boulonnais and Belgian Coal-fields in the Geol. Soc. Journal, to the 12th vol. of which MM. Degousée and Laurent have contributed a valuable notice of the Valenciennes

We have seen that the strata constituting a coal-field are alternating layers of coal, clay, shale, and sand, of variable thickness, usually based either on grit, or on limestone abounding in marine shells and corals. Now, a very remarkable fact is the nearly uniform presence of an often thick bed of earthy clay beneath every layer of coal, and a stratum of slaty clay or shale above it; together forming a triple series, presenting the following characters:—

(1.) Lowermost;—a stratum of clay, called, from its position, the *Under-clay;* a tough argillaceous substance, which upon drying becomes a grey friable earth. Occasionally this clay is of a black colour from the presence of carbonaceous matter. This bed almost invariably contains an abundance of the fossil vegetables termed *Stigmariæ,** which are root-like bodies, generally of considerable length, and have rootlets or fibres attached, which extend in every direction through the clay. These great roots commonly lie parallel with the planes of the stratum, and nearer to the top than to the bottom.

(2.) *Coal.* A carbonized mass, in which both the external forms and internal structure of the plants and trees composing it are almost entirely

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Coal-basin. Naumann, Hoffmann, Sternberg, Villefosse, Rœmer, Dechen, Herzog, Gutbier, Freiesleben, Leonhard, Cotta, Geinitz, Gœppert, and Beinert are chief among those who have treated of the Coal-fields of Germany. The coal of Russia is described in full by De Verneuil, Keyserling, and Murchison.

A long series of papers having reference to the Coal-fields of New Brunswick and Nova Scotia, published in the Proceedings and Quarterly Journal of the Geological Society, are enumerated in an appendix to Mr. Dawson's very instructive account of the Joggins Coal-measures in the 10th vol. of the Geol. Society's Journal (p. 41). The "Acadian Geology," by the same author, is also an important work in the literature of the coal. Mr. W. R. Johnson's "Report on American Coals," 1844, and especially the late R. C. Taylor's valuable "Statistics of Coal," should be consulted by the student, where abundant references to books and papers treating of British, European, American, African, Asiatic, and Australian coals will be found.

* See the description of coal-plants further on; also Medals of Creation, p. 133; Pict. Atlas, Org. Rem. pl. 3, *fig.* 1, and plates 21—23; *and the Supplementary* Notes, Pict. Atlas, p. 198.

obliterated, though traces of woody tissue are observable. Large trunks, stems, and leaves are rarely distinguishable in it.

(3.) *The Roof*, or upper bed. This generally consists of slaty clay, abounding in trunks, branches, leaves, and fruits; it also includes layers and nodules of iron-stone, enclosing leaves, insects, crustaceans, &c. In some localities argillaceous or calcareous beds of fresh-water shells, and in others of marine shells, are intercalated; and layers of shale, finely laminated clay, micaceous sand and grit, and pebbles of limestone, granite, sand-stone, and other rocks often occur. Pebbles of iron-stone, and even of coal, derived from the destruction of older iron-stones and coal-beds, have been found in coal-seams. Some of the most illustrative specimens of the leaves, fruits, &c. of the carboniferous flora are found in these shales and sandy beds, which appear to have been the accumulations of water-worn detritus of other rocks, promiscuously intermingled with the dense foliage and stems of prostrate forests; the whole having been drifted from a distance by strong currents or floods, proving that considerable time elapsed during the formation of these coal-measures,—sufficient indeed for the consolidation and denudation (and possibly upheaval also) of one set of deposits before the later beds were formed.* The evidences of the partial removal of coal-seams, shales, and sand-beds, in the coal-measures, point also to the length and many changes in the coal-era.†

7. Mode of deposition of the Coal.—Thus we find, in the first place, spread uniformly over the bottom, and constituting the foundation on which the coal reposes, a stratum of fine clay (under-clay), sometimes several feet thick, which possibly may have once constituted the soil of vast plains or savannahs. Almost the only fossil remains found in it, except in a few localities, are the roots of the large trees of which the coal is in a great measure composed; for such the common *Stigmariæ* now prove to be, and not floating aquatic plants, as was formerly supposed. The invariable occurrence of the fossil roots, termed *Stigmariæ*, in the under-clay, and their rarity in the coal and shale, was noticed by Martin (*Petrif. Derbiensia*), Steinhauer, Maccul-

* See De la Beche's Geol. Observ. 2nd edit. p. 511.

† *Ibid. p. 514; and Quart.* Journ. Geol. Soc. vol. vi. p. 124; vol. vii. *p. 246; and vol. x. p. 12.* Rep. Brit. Assoc. 1838, Sect. p. 79.

loch, and other observers: but the importance of this fact was not duly appreciated until Logan drew attention to it. In the Welsh coal-field, in a depth of twelve thousand feet, there are sixty beds of coal, each lying on a stratum of clay abounding in Stigmariæ. In the Appalachian coal-field of the United States, and in the well-exposed coast-sections of the Coal-formation in Nova-Scotia, the same phenomenon appears.

Upon this under-clay is a bituminous mass of indistinguishable plant-remains (*Coal*). Occasionally stems of trees are found passing vertically through or lying in the coal-bed.

In the third place, we have a deposit of drifted materials promiscuously intermingled with the foliage and stems of numerous kinds of terrestrial plants (*Roof*); the whole often appearing to have been subjected to the mechanical action of water, both in its origin, and sometimes after its first deposition as a sand or mud-bed.

These facts seem to indicate that a bed of coal of this kind may have been either a submerged forest or a swampy jungle. The *under-clay* was the natural soil in which the Stigmariæ, the roots of the trees (Sigillariæ) forming the coal above, originally grew; the *coal*, the carbonized stems and foliage of the trees to which the roots belonged; and the upper stratum, or *roof*, may have either resulted from detritus transported from a distance by a debacle or flood, which overwhelmed and buried the foliage and stems of the prostrate forest, or may have been swept over it more or less rapidly by the encroaching tides on a low and sinking well-forested coast-line.

These phenomena may thus be explained by supposing that a plain, densely clothed with vegetation, was inundated by an irruption of the sea; or overwhelmed by a flood of water from an inland lake, occasioned by the sudden removal of some barrier; or by the slow subsidence of the tract of country on which the forest or jungle grew. But when we find *an uninterrupted* series, in which triple deposits of this kind are repeated thirty or forty times, and through a thickness of several thousand feet, this solution of the problem, though very plausible, is not without its difficulties. Not only subsidence after subsidence must have taken place, but the first submergence have been followed either by an elevation of the land, or a very gradual reconstitution of a sub-aërial surface; and then another soil capable of affording support to a second forest must have been produced, and another generation of vegetables, of the same species as the former, have sprung up, and arrived at maturity: and again another subsidence, followed by an accumulation of drift. And these periodical oscillations in the relative level of the land and water, and successive reproductions of vegetable soil and of forests, must have gone on uninterruptedly through an incalculably long period of time; not in one district or country only, but in various parts of the world, during the same geological epoch.

Some seams of coal attain an enormous thickness. In England, the thickest bed of coal, amounting to thirty feet, is in the Dudley basin. In the Great Exhibition of 1851, there was exhibited a fine section of the lowermost bed of coal (known as the "Thick Coal" *), from Tividale colliery in South Staffordshire, the total thickness of which was 29 feet; with no intermixture of sediment except some shaly partings, a few inches thick. A shed was erected for its exhibition on the outside of the west-end of the Crystal Palace; beside it were placed some large stems of Sigillariæ.

"It is not, however, to be supposed," says Prof. Phillips,† "that this enormously thick seam is a single bed of coal; it is, in fact, composed of thirteen different beds locally accumulated together, with certain partings, which in other places swell out into considerable thicknesses of shale. Thus the upper part of the 'ten-yard coal' separates from the rest of the beds, and under the title of the 'flying reed,' becomes a totally distinct bed in the northern part of the coal-tract." ‡

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* See Jukes's Memoir on the South Staffordshire Coal-field (Geol. Surv. Records), 1853, p. 173, 184, &c. This careful and well-illustrated description of a typical coal-field contains not only the good practical information to be expected from the labours of so sound a geologist as Mr. Jukes, but also many valuable theoretical suggestions on the origin of coal and the physical characters of the old carboniferous area.

† Manual Geol. p. 192.

‡ Humboldt refers also to some very thick coal-seams in Scotland and Burgundy, *Cosmos*, vol. i. p. 284. For Mr. Bowman's views of the probable *circumstances under* which separate coal-seams run into each *other, see Lyell's "Manual,"* p. 330.

Mr. Dawson describes the "Main-coal Seam," of the Albion Mines (New Brunswick), a specimen of which was extracted by Mr. H. Poole for the New York Exhibition, 1853, as being 38 feet 6 inches thick, of which only 2 ft. 4½ in. consisted of the "roof-shale," intercalated carbonaceous shale and ironstone, and "under-clay." *

In some districts (as in the coal-beds of the Mountain-limestone of Southern Russia and of the North of England) the vegetables of which the coal is formed apparently consist of broken and drifted plants, carried into the sea by inundations and freshets of rivers; in this case, the layers of clunch or finely levigated shale which support the coal-seams may have originated from the earthy debris brought down by the floating masses of terrestrial plants.†

8. THE GREAT DISMAL SWAMP OF VIRGINIA. — The formation of the coal-measures from terrestrial trees and plants, not drifted, but growing on the areas now occupied by the coal, is strongly advocated by Sir C. Lyell: and the following notes from the observations of this profound geologist, on the "*Great Dismal Swamp*" of Virginia, in North Carolina, afford an interesting illustration of this hypothesis.

The "Great Dismal," is a morass forty miles long, and twenty-five miles in its greatest width, and has the appearance of a broad inundated river-plain, covered with all kinds of aquatic trees and shrubs, the soil being as black as in a peat-bog. It is one enormous quagmire, soft and muddy, except where the surface is rendered partially firm by a

* Quart. Journ. Geol. Soc. vol. x. p. 47.

† Sir R. I. Murchison.—The following remarks of an eminent French geologist, Constant Prévost, are especially worthy of attention in relation to this subject:—"On n'a pas assez réfléchi lorsque l'on a dit que les formations fluvio-marines n'étaient que des accidents locaux d'embouchure et de golfe; on pourrait presque avancer, sans paradoxe, que dans certaines mers bordées de vastes continents, les eaux douces affluentes produisent plus dans la mer, que les eaux marines elles-mêmes. Le Missisipi et ses tributaires enlèvent au continent qu'ils traversent plus de matieres sédimentaires et de corps organisés, pour les porter dans la mer, que les vagues de celles-ci n'en prennent sur tout le pourtour des deux Amériques; et l'on sait, par de journaliers exemples, que des végétaux apportés par ce fleuve, des rives du Missouri dans le golfe du Mexique, vont atterrir sur les côtés d'Islande, et même du Spitzberg."—*De la Chronologie des Terrains et du Synchronisme des Formations.* 1845.

covering of vegetables and their matted roots; and is actually higher than nearly all the firm and dry land which encompasses it; and, to make the anomaly complete, in spite of its semi-fluid character, it is higher in the interior than towards the margin. The soil of the swamp is formed of vegetable matter, usually without any admixture of earthy particles. We have here, in fact, a deposit of peat from ten to fifteen feet in thickness, in a latitude where, owing to the heat of the sun and length of the summer, no peat-mosses like those of Europe would be looked for under ordinary circumstances. The juniper trees, or white cedars (*Cupressus thuyoides*), stand firmly in the softest part of the quagmire, supported by their long tap-roots, and afford, with many other evergreens, a dark shade, under which a multitude of ferns, reeds, and shrubs, from nine to eighteen feet high, and a thick carpet of mosses, spring up, and are protected from the rays of the sun. Where these are most powerful, the large cedar (*Cupressus disticha* or *Taxodium distichum*) and many other deciduous trees are in full leaf. The black soil formed beneath this shade, to which the mosses and leaves make annual additions, is a soft black mud, without any traces of organization. Numerous trunks of large and tall trees lie buried in the black mire of the morass. In the midst of the swamp there is a lake of an oval form, seven miles long, five wide, and the depth, where greatest, fifteen feet; its bottom consists of mud like the swamp, but which in some places is covered by a pure white sand, a foot deep. This sheet of water is usually even with the banks, on which a tall and thick forest grows.

The phenomena above described help us greatly to conceive the manner in which the coal of the ancient carboniferous rocks may have been formed. The heat, perhaps, may not have been excessive when the coal-measure originated, but the entire absence of frost, with a warm and damp atmosphere, may have enabled tropical forms to flourish in latitudes far distant from the line. The frequent submergence of masses of vegetable matter like the morass, beneath seas or estuaries, as often as the land sank down during subterranean movements, may have given rise to depositions of strata of mud, sand, or limestone, immediately upon the vegetable matter. The conversion of successive surfaces into dry land, on which other swamps supporting trees were formed, might give origin to a continued series of coal-measures, of great thickness.*

The above is a concise exposition of this theory by one of its ablest advocates, and is therefore deserving every consideration; and the more so, since the same philosophical

* *Travels in North America*, vol. i. chap. vii.

observer has brought forward a plausible explanation of the perplexing enigma presented by the purity of the coal itself from sandy and earthy particles, and by the comparatively great thickness of many coal-seams. He adduces as illustrative of the probable origin of such coal-beds, the existing conditions of the "Sunk Country," in the valley of the Mississippi, and other of the great "cypress-swamps" of that region, where great areas of rapidly accumulating vegetable matter are protected by thick marginal belts of reeds and brushwood, which effectually resist the introduction of any of the detrital matter suspended in the waters of the annual inundations.*

9. UPRIGHT TREES IN THE COAL-MEASURES.—The occurrence of trees in an upright position, in some instances with their roots attached, and extending into the under-clay, is regarded as another unequivocal proof of the formation of coal from vegetables growing on the spot.

Several instances of this kind have been observed in England. One of the most remarkable was brought to light (from 1837 to 1846), in the excavations for the Bolton and Manchester Railway, near Dixonfold, where five large stems (*Sigillariæ*) were found erect, with their roots extending into a layer of impure clay below, in which were found many specimens of the fossil cones known as *Lepidostrobi*.† They stood on the same plane, and near to each other. The trunks were surrounded and filled by a soft blue shale, the carbonized bark (or, rather, the thin outer cylinder of woody tissue) being all that remained of the original structure. The stems are gnarled and knotted, and have decorticated prominences, like those in barked trunks of our old dicotyledonous trees. All these trunks appear to have been broken off by violence at a height of four or

* Manual of Geology, 5th edit. p. 385. The subject of the origin of coal-beds, both on the hypothesis of the accumulation of plants growing in place, and on that of the drifting of masses of plants, is ably treated in De la Beche's "Geological Observer," and in Phillips' "Manual of Geology." See also Williamson's Remarks, Rep. Brit. Assoc. 1842, Sect. p. 48.

† *Medals*, p. 141.

five feet above the roots, and no traces of the upper part of the stems or branches were detected.*

Mr. Binney has described a very interesting specimen of a rooted stump of a Sigillaria met with in a colliery at Dunkinfield, about seven miles east of Manchester.†

In constructing the railway-tunnel at Clay-cross, a few miles south of Chesterfield, through the middle portion of the Derbyshire coal-measures, in 1838, a group of nearly forty trees (*Sigillariæ*) was discovered. These stood at right angles to the planes of stratification, and not more than three or four feet apart.‡

In the Derwent Mines, Durham, at the depth of fifty-five fathoms, among numerous examples which were lying in horizontal layers, were several in an erect position. Two stems of Sigillariæ, situated in the space cleared out to get at the lead-ore, stood upright, having their roots firmly impacted in a bed of bituminous shale; they were five feet high, and two in diameter.‖

In the Newcastle coal-field, a stratum of sandstone occurs 150 yards below the surface, in which were observed many erect stems of trees, from two to eight feet in circumference, having their roots in a thin layer of coal.§

On the coast of Northumberland, within the length of half a mile, twenty upright trees were observed in 1816, by Mr. Trevelyan; ¶ and similar fossils were noticed many miles distant from this spot, in the same coal-field, as if they were a continuation of a submerged forest, the trees of which had maintained their erect position, like those of the Isle of Portland (p. 399). Examples of isolated upright trunks, with more or less of the roots attached, are not uncommon.

In Glamorganshire De la Beche and Logan observed a fine group of upright Sigillariæ.**

* Medals, p. 125; Geol. Transact. 2 ser. vol. vi. p. 173, pl. 17; and Geol. Proceed. vol. iii. p. 139 and 269. Owing to the scientific zeal of Mr. Hawkshaw, F.G.S., who originally described these interesting relics, of a palæozoic forest, they have been carefully preserved in their natural position. See also Trans. Manchester Geol. Soc. vol. i. p. 112.

† Geol. Journ. vol. ii. p. 390.

‡ Geol. Proc. vol. iii. p. 272.

‖ Observations on Fossil Vegetables, by Henry Witham, 4to; Edinburgh, 1831, p. 5.

§ *Ibid.* p. 7.

¶ Buckland Bridg. Treat. p. 470.

** Mem. Geol. Survey, vol. i. p. 183.

10. Upright Trees at Wolverhampton and St. Etienne.—The following examples may also be adduced.

In a colliery near Wolverhampton the bottom coal rises to view, and where the surface has been cleared of the alluvial covering, it presents "the appearance of a moor on which a full-grown fir-wood had been cut down a few months before, and only the stumps left behind. Stump rises beside stump, to the number of seventy-three in all: the thickly diverging roots strike out on every side into what had been once vegetable mould, but which now exists as an indurated brownish-coloured shale. Many trunks, sorely flattened, lie recumbent on the coal, some of them full thirty feet in length, while some of the larger stumps measure rather more than two feet in diameter. There lie thick around Stigmariæ, Lepidodendra, Calamites, and fragments of Ulodendra; and yet, with all the assistance which these lent, the seam of coal formed by this ancient forest does not exceed five inches in thickness. . . . . . Not a few of the stumps in this area are evidently water-worn. . . . . . The prostrate forest had been submerged, and mollusks lived and fishes swam over it." This upper forest is underlaid by a second, and even a third; we find three full-grown forests closely packed up in a depth of not more than twelve feet.*

A coal-pit at Treuille, near St. Etienne, Department of the Loire, in France, described by M. Alexandre Brongniart, contains many stems of Calamites and other trees in an erect position; and this fact is generally considered as an indisputable proof that the coal was produced by the submergence of a forest that once grew on the spot: but as many of these stems are inclined at various angles, and their roots implanted in different beds, the perpendicularity of the upright trees is possibly accidental. This mine is most favourable for observation, for it is in the open air, and exposes to view a natural section of the strata of clay, shale, and coal, with four layers of compact iron-ore, in flattened nodules, which are accompanied, and even penetrated, by vegetable remains. The upper ten feet of the quarry consist of micaceous sandstone, which is in some instances stratified, and in others possesses a slaty structure. In this bed are numerous vertical stems traversing all the strata, and appearing like a forest of plants resembling the Bamboo or large *Equiseta*, turned into stone, in the place on which it grew. The stems are of two kinds:

* First Impressions of England and its People, by Hugh Miller, p. 223 (Edit. 1857, p. 202). This fossil forest is described and illustrated by *Messrs. H.* Beckett and W. Ick, in the Geol. Soc. Journ. vol. i. p. 41.

the one long and slender, from one to four inches in diameter, and nine or ten feet high, being simply jointed and striated solid cylinders of sandstone, with a thin coaly bark; the other and less common species are hollow cylindrical stems, spreading out from the base like a root, but without ramifications.*

11. Upright Trees in the Coal-Measures of Nova Scotia and Cape Breton.—Numerous erect trees in the Cape Breton coal-measures have been observed and described by Mr. R. Brown,† many them having their roots and rootlets still attached. And, though it is unnecessary to multiply examples of the occurrence of trees in an upright position in the carboniferous deposits, this phenomenon is so strikingly displayed in the coal-measures of Nova Scotia, and has been so well described by Logan, Dawson, and Lyell, that I cannot omit a short account of the erect stems in the cliffs of the Bay of Fundy:—

In the coal-measures on the southern shores of a branch of the Bay, there are ten successive stages of erect trunks of trees, placed at right angles to the planes of stratification, through a thickness of strata of 2500 feet; the entire series of deposits is estimated to be five miles in thickness. The strata are inclined at an angle of between 25° and 30°. The trunks of the trees are often mere hollow cylinders, consisting of the bark in the state of pure coal, and filled with sand and clay, containing leaves of ferns and other plants, and in one instance thé bones of a small reptile and the shell of a land-snail.‡ A trunk, fourteen inches in diameter, had a coating of bark a quarter of an inch thick. Beds of bituminous shale and clay with Stigmariæ, ten feet thick, are described as overlying one series of upright trees, and upon these was another bed of coal, one foot thick, that supported two trees, each eleven feet high, and sixty yards apart.§

* Notice sur des Végétaux Fossils traversant les couches du Terrain Houiller, par M. Alex. Brongniart, Paris, 1821. See also De la Beche's "Geological Memoirs," 1824, for a translation of M. Beaunier's description of the coal-district of St. Etienne, with a drawing of the quarry and upright stems.

† Geol. Soc. Proceed. vol. iv. p. 176; Journ. vol. ii. p. 393; vol. iv. p. 46; and vol. v. p. 354.

‡ Journ. Geol. Soc. vol. ix. p. 58.

§ See the Section of the Cliffs of the South Joggins, near Minudie, Nova Scotia; Travels *in North America*, vol. ii. p. 180, fig. 21.

In the Joggins section many of the erect trees appear without roots; which circumstance is explained by Mr. Dawson, 1st, by the fact that in the exposed cliff the under-clays, with the roots, weather away, leaving the stumps still supported by the overlying and harder sandstone; and 2ndly, by the supposition that often the roots have been incorporated with the coal-seams.* These trunks often resemble those found erect at Dixonfold, in England; but some are decidedly *Sigillariæ*. A few of the upright trees appear to be true *Coniferæ*.

At Pictou, a hundred miles to the eastward of the Minudie coal-measures, the same group of deposits occurs, and yields a large supply of coal. In this locality there is a row of upright *Calamites*, in sandstone, all terminating downwards at the same level, where the sandstone joins a layer of coarse grey limestone with pebbles. The tops of the Calamites terminate at different heights, where the grit becomes coarser; and have not been removed by decay, but have evidently been broken sharply off, sometimes presenting at the summit a crushed appearance, like that of a hollow cylinder of paper bent at right angles. The bed of erect Calamites at St. Etienne (p. 688) is regarded by Sir C. Lyell as analogous; and he considers both localities as affording unequivocal proof of fossil trees occupying the ground on which they originally grew.† Sir C. Lyell has also described a good example of numerous upright and rooted fossil trees (*Sigillariæ*) as occurring in the coal-measures of Indiana, at Kimball's Mill, near Evansville.‡

To account for the several series of these erect trees at successive stages on the supposition that the trunks are now standing in their original position, we must suppose periodical subsidences of the land to have taken place. "It by no means follows," observes Sir C. Lyell, "that a sea four or five miles deep was filled up with sand and sediment. On the contrary, repeated subsidences, such as are required to explain the successive submergence of so many forests which grew one above the other, may have enabled this enormous accumulation of strata to have taken place in a sea of moderate depth." §

* Quart. Journ. Geol. Soc. vol. x. p. 30.

† Travels in North America, vol. ii. p. 195; Dawson, Quart. Journ. Geol. Soc. vol. vii. p. 195; and "Acadian Geology," 8vo, 1815.

‡ Second Visit to the United States, vol. ii. p. 272.

§ *Travels in* North America, vol. ii. p. 190.

12. Coal-shales and Vegetable Remains. — I have already stated that it is from the shales, or slaty coal of the roof, that the most abundant and illustrative examples of the plants of the carboniferous epoch are obtained; in many layers, vegetable remains occur between every lamina, the entire mass being formed of carbonized leaves and stems, closely pressed together in clay.* The carbonaceous matter is sometimes in an unconsolidated state, exhibiting the matted fibres, leaves, and stems. This condition, indicating an intermediate stage in the formation of coal, is not of unfrequent occurrence in the secondary and tertiary carbonaceous deposits, but is rare in the most ancient.†

The roof of a coal-mine, when newly exposed, displays the most interesting spectacle imaginable; leaves, branches, and stems, of the most elegant and delicate forms, being embossed on the dark shining surface.‡ The coal-mines of Bohemia, the fossil plants of which are well known, from the beautiful work of Count Sternberg,§ are stated by Dr. Buckland to be the most interesting of any he has visited,—but I will describe them in his own eloquent language. "The most elaborate imitations of living foliage upon the painted ceilings of Italian palaces bear no comparison with the beauteous profusion of extinct vegetable forms, with which the galleries of these instructive coal-mines are overhung. The roof is covered as with a canopy of gorgeous tapestry, enriched with festoons of the most graceful foliage, flung in wild irregular profusion over every portion of its surface. The effect is heightened by the contrast of the coal-black colour of these vegetables with the light ground-work of the rock to which they are attached. The spectator feels transported, as if by enchantment, into the forests of another world; he beholds trees of form and character now unknown upon the surface of the earth, presented to his senses almost in the beauty and vigour of their primeval life; their scaly stems and bending branches, with their delicate apparatus of foliage, are all spread forth before him, little impaired by the lapse of in-

* Mem. Geol. Survey, vol. i. p. 193, fig. 18.

† Silurian System, p. 100.

‡ See Mr. R. C. Taylor's notice of fossil Arborescent Ferns, Sigillaria, and other Coal-plants, exhibited in the roof and floor of a coal-seam in Dauphin County, Pennsylvania. Trans. Amer Phil. Soc. 2 ser. vol. ix. p. 219, *Philadelphia, 1843.*

§ Flore du Monde Primitif.

definite ages, and bearing faithful records of extinct systems of vegetati which began and terminated in times of which these relics are the inf uible historians. Such are the grand natural herbaria wherein these m ancient remains of the vegetable kingdom are preserved in a state of tegrity little short of their living perfection, under conditions of our pla which exist no more." *

13. MILLSTONE-GRIT.—The coal-measures north of t Trent are superposed on the group of coarse sandy a pebbly deposits designated by this term; but to the sou these strata appear as a hard sandy rock (" Farewell-rock '

The most characteristic bed of this series is the quartzose conglom ate, termed millstone-grit, which consists of rolled fragments of quar rock and granite, of various sizes, from that of a pear downwards, mented together in some instances by an argillaceous, in others b crystalline silicious paste. Sandstones composed of the fine detritus similar materials are associated with the grit. Water-worn fragments shale, coal, red-sandstone, stems of plants, &c., all bearing marks transport by currents and streams, are also often found imbedded the in. Beds of coal are occasionally interpolated in this series, and in so localities the lowermost strata consist of shales with coal-plants, and c tain nodules of ironstone similar to those of the upper coal-strata, veins of lead and copper. Satin-spar, and naphtha, petroleum, and o bituminous substances, occasionally occur in the shales of this series. In Yorkshire the Millstone-grit is an important deposit, contai several subordinate beds of coal; and is separated from the great inf calcareous group (known in the north of England as the *Scar-limest* by deposits, not less than 1000 feet thick, equivalents of the *Upper L stone-shales* of Derbyshire, and known as the *Yoredale-rocks*, in w five series of limestone-strata, remarkable for their continuity and reg thickness, alternate with great masses of sandstone and shale, contai innumerable impressions of coal-plants, and a few seams of coal.†

In a sandstone belonging to this series, from the Hutt Roof Mine, Mr. Binne ‡ has recognised trails of Mollus and of Annelids; and in the Millstone-grit of Tintwistl

* Bridgewater Treatise, p. 458.

† Professor Sedgwick, "Anniversary Address," 1831, Proc. Geol. Soc vol. i. p. 286; Phillips, "Geol. Yorkshire," and "Manual Geol." 1855

‡ *Trans. Phil.* Lit. Soc. Manchester, 2nd ser. vol. x. p. 181.

Cheshire, the same indefatigable explorer of the Coal-formations of Central England has discovered* fine tracks of a probably reptilian quadruped, similar to, but of much larger proportions than even that which has left on the Permian sandstones of Corncockle Muir the impressions referred to *Chelichnus Titan* by Sir W. Jardine. Prof. Harkness also has recognised Annelid tracks in the Millstone-grit† (Ireland).

14. CARBONIFEROUS OR MOUNTAIN LIMESTONE.—Beneath the Millstone-grit and Upper Limestone-shale, and indeed intimately connected with the latter, is the great calcareous member of the lower portion of the Carboniferous system. This is an extensive assemblage of calcareous strata, composed for the most part of subcrystalline grey limestone, disposed in beds of considerable thickness; the strata through a depth of many hundred feet being separated only by very thin clay-partings. Shales and grits are intercalated in certain localities; and in some countries important beds of coal are situated in this division of the system. Layers and nodules of chert occasionally traverse the limestones, like the flints in chalk.

The term *Mountain-limestone*, applied to these calcareous rocks, has originated from their often forming elevated mountain-chains, as in Derbyshire, Yorkshire, Somersetshire, &c., giving rise to scenery which equals, if not surpasses, in picturesque beauty that of any other part of England. I need but mention the vale of the Avon at Clifton, Matlock-dale, Dovedale, the escarpments that overhang the Wye near Chepstow, &c. The magnificent gorge of the Avon at Clifton is flanked by an uninterrupted succession of mural precipices, known by the name of St. Vincent's Rocks, and presents an unrivalled natural section of the Carboniferous limestone. The calcareous beds rest on strata of the Devonian series, which may be seen on both sides of the river, near Cook's Folly, extending on the south under Leigh-down and Weston-down.‡

* Quart. Journ. Geol. Soc. vol. xii. p. 350.

† Edin. New Phil. Journ. new series, vol. i. p. 278.

‡ Descriptions and sections of these rocks have been made by Dr.

This series of strata is also remarkable for the deep chasms and fissures by which the rocks are traversed; the principal caverns of this country being situated in them; those of Derbyshire, Yorkshire, Somersetshire, &c., are well known. Swallow-holes and subterraneous rivers are likewise frequent throughout the districts formed by these deposits.

The mountain-limestone is largely developed over the central and northern parts of England, and the south-west of Scotland: and it is the predominant rock throughout the greater part of Ireland. In Somersetshire, Gloucestershire, Shropshire, North and South Wales, and Derbyshire, it constitutes an almost entirely calcareous mass, interposed between the Devonian group below (or, where that is wanting, the more ancient Silurian rocks) and the upper shales, grits, and coal above. In Cumberland, and Westmoreland, &c., it appears as an elevated belt, which partly surrounds the Cumbrian slate-mountains, and forms, on the west, a ridge nearly three thousand feet in height.

In Northumberland the mountain-limestone, modified by intercalated shales and coal-beds, and associated with the overlying millstone-grit, occupies large areas, and constitutes ranges of hills of considerable elevation; the geographical features strongly contrasting with those of the adjacent country on the south, which consists of the upper coal-bearing strata, spread out in a plain of great extent.

In Derbyshire the grand physical features of the country are produced by the mountain-limestone, which rises into crags or peaks, and hills, presenting bold precipitous escarpments, and produces the wildest and most picturesque scenery. Professor Phillips estimates the thickness of the lower division of limestones, with shale-partings, in Derbyshire at 750 feet; the alternations of shale, sandstone, limestone, and ironstone, which surmount the former, at 500 feet; and the cappings of millstone-grit which form the summits of the hills, at 360 feet.

The Carboniferous Limestone, though some of the beds are destitute of fossils, is for the most part largely made up of corals, crinoids, shells, &c.; these often form three-fourths of the mass. Of the 1900 feet thickness of Mountain-limestone in South Wales, the lower half may be said to be made up of *Crinoidea* and *Strophomenæ*, and the upper portion of

Bright (Geol. Trans. vol. iv. p. 193); Mr. Cumberland (*ibid.* vol. v. p. 95); Buckland and Conybeare (*ibid.* 2 ser. vol. i. p. 210); De la Beche and Williams, Mem. Geol. Surv. vol. i. p. 113; Lonsdale, Murchison's Sil. Syst. p. 158. See also Excursions to Clifton, Matlock, and Crich Hill; Medals of Creation, vol. ii. pp. 864, 867, 880.

corals (De la Beche and Phillips). We reserve a more particular notice of these organic remains for a subsequent part of this Lecture. The Derbyshire encrinital marbles (see p. 660), and the coral-marbles of St. Vincent's rocks, near Clifton, are well-known examples of the finer compact varieties of these calcareous deposits.

In the Bristol and Mendip district, some beds of this great limestone have an oolitic structure,* the spherules containing grains of sand, water-worn fragments of shells and other organic substances, or the little shells of foraminifera.

The chert, where interpolated among the crinoideal remains, contains beautiful casts and impressions of the stems and ossicula, and also of the associated shells, in consequence of the silicious matter, which surrounded and penetrated these bodies, having resisted the chemical action that subsequently destroyed the calcareous structure of the originals.†

15. Derbyshire Lead-mines.—It is in the mountain-limestone that the principal British lead-mines are situated, namely, those of Somerset, Derbyshire, York, Flint, Durham, and Northumberland. In Derbyshire the metal occurs in numerous veins which traverse the strata, and extend in some instances into the *toad-stone*,—a volcanic rock which we shall describe in the sequel. The perpendicular veins (*rake-veins*) are from two to forty feet wide; and there are chasms or hollows in the rock, several hundred feet in width, which also contain metallic ores and spars. Manganese, copper, zinc, and iron are found in the limestone; but the predominating metalliferous ore is the sulphide of lead, or galena. This substance is of a bluish-grey colour, and often occurs in

* This is not the oldest instance of the occurrence of the oolitic structure in rocks. It is present in some parts of the Bala limestone. As more modern instances, may be mentioned oolitic beds in the Zechstein of the Permian, and the Muschelkalk of the Trias.

† See the pulley-stone, *Lign.* 152, *fig.* 1, which is a silicious cast of an encrinital *column.*

cubic and octahedral crystals; it is also disposed in thin layers, as well as in veins. It is accompanied by fluor-spar, calc-spar, sulphate and carbonate of barytes, iron-pyrites, &c. The variety termed specular galena, or *slickensides*, is a thin coating of lead on the sides of the veins, and appears to have arisen from one wall of the fissure having slipped along the face of the other, so as to give it a polished or *slicken* surface.

The beautiful mineral known by the names of *fluor-spar*, *chlorophane*, and *Derbyshire spar*, and provincially called *Blue-John* and *Bull-beef*, so much in request for vases and other ornamental purposes, is a fluate of lime,* found in the state of veins, and in large irregular masses from three inches to a foot in thickness, in the Odin mines, near Castleton, in Cornwall, and elsewhere.

The structure of the country around Matlock and the principal metalliferous districts of Derbyshire are so fully described in various works, that the present brief notice of the manner in which the mineral and metallic productions occur will suffice. The chasms in the limestone exposed in some of the quarries are often more or less incrusted with minerals and spars, and exemplify the mode in which the rich metallic veins of lead are distributed in the interior of the mountains. A fissure which I observed in a quarry in Crich Hill will serve as an illustration. A layer of the dark blue-grey sulphide of lead, or *galena*, was spread over the surface of the limestone that formed the walls of the fissure, upon this was deposited a layer of white baryt-spar, and on the latter was a coating of cubic crystals of fluor-spar of a light-blue colour. Usually the fissure is filled up by alternating layers of crystalline veinstones enclosing a central vein or "rib" of galena.

16. CARBONIFEROUS ROCKS OF DEVONSHIRE.—The rapid

* This appears to have been the enigmatical substance of which the almost priceless "Myrrhine vases" of ancient Rome consisted. (Fraser's Mag.)

sketch above given of the principal features of the three groups of strata composing the Carboniferous system affords a general idea of the prevailing characters of this important formation. There is, however, an extensive series of rocks which belong to this epoch, but occur under conditions that have rendered their relations somewhat obscure, and occasioned them to be classed with the more ancient beds, until the investigations of Professor Sedgwick and Sir R. I. Murchison demonstrated their true position in the chronological

Fig. 1.

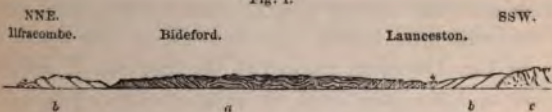
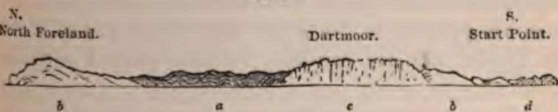


Fig. 2.



LIGN. 159.—SECTIONS OF THE STRATA OF DEVONSHIRE.

Fig. 1. Section from NNE. to SSW. showing the carboniferous strata (*a*) in the centre, resting on each side on schists and sandstones of the Devonian series (*b*, *b*); a protrusion of granite (*c*) occurring on the SSW.

— 2. Section from north to south: the carboniferous beds (*a*) repose on Devonian strata on the north (*b*); while towards the south the granite of Dartmoor has been protruded (*c*); the Devonian series (*b*) re-appears in the southern part of the county, terminated by a band of micaceous schists (*d*).

a, Culmiferous rocks of Devonshire: grits, schists, culm, and Posidononomya-limestone.

b, Devonian rocks: Clymenia-limestone and schists, sandstones, Stringocephalus-limestone and schists, conglomerates, sandstones, and lowest schists.

c, Granite.

d, Micaceous schists; altered or metamorphosed strata.

arrangement of the British strata.* This group consists of shales, limestone, and slaty coal (provincially called *culm*), constituting a trough of carboniferous deposits super-im-

* Geol. Transact. 2 ser. vol. v. p. 633, &c.; Report British Assoc. 1836, sect. p. 96; *Phil. Mag. vol.* xiv. p. 241, &c.; Edinb. New Phil. *Journ. vol. xliii. p. 33; Quart.* Journ. Geol. Soc. vol. viii. p. 8, &c.

posed on "Devonian" strata, but much dislocated and altered in character by intrusions of granitic rocks.

The culmiferous deposits of Devonshire were once connected with the coal-formation of South Wales, on the north side of the Bristol Channel: the fossil vegetables which they contain appear to be identical with those of the coal-basin of South Wales. In the section, *fig.* 1, through Devonshire from NNE. to SSW. the culmiferous beds (*a*) are seen to occupy a trough, and to repose on each side on the schists and calcareous sandstones (*b*, *b*) of the *Devonian* or Old Red series. The section (*fig.* 2) from north to south shows the carboniferous strata (*a*), flanked on the north side only by the Devonian rocks (*b*), the granite of Dartmoor (*c*) having been protruded on their southern edge; while the Devonian rocks re-appear in the southern part of the county, terminated by a band of micaceo-chloritic schists, which are parallel to the great disturbing axis of Cornwall and Devon, and are probably metamorphosed sedimentary deposits.*

17. TRAP-ROCKS AND TRAP-DYKES OF THE CARBONIFEROUS SERIES.—The coal and its associated strata everywhere exhibit proofs of the violent subterraneous movements which they have undergone since their original deposition; and but few coal-fields are free from extensive faults and dislocations, by which the beds have been broken up and thrown into different levels and positions. The entire group is also often traversed by veins and dykes of intruded volcanic rocks; generally consisting of the hard, dark-green, fine-grained stone, called *trap*.

In Yorkshire there is a trap-dyke of prodigious extent and thickness, named the *Whin-sill*, which traverses the coal-measures, red sandstones,

* Besides the above-quoted works by Sedgwick and Murchison on the Culmiferous beds of Devonshire, the reader should also consult De la Beche's "Report on Cornwall, Devon, and West Somerset," Phillips's "*Palæozoic* Fossils of Devon," &c., and the first vol. of the "Mem. Geol. *Survey;*" and Sir R. Murchison's "Siluria."

and lias, and passes from High Teesdale to the confines of the eastern coast; a distance of upwards of sixty miles.

In Derbyshire, a trap-rock, in many parts amygdaloidal, and which, from being mottled with green and yellow, has received from the miners the name of *toad-stone*, is interpolated between the beds of mountain-limestone of that country, under circumstances of considerable interest.*

These phenomena can nowhere be studied with more advantage than in the neighbourhood of Matlock, which is a region of carboniferous limestone, broken up and traversed by volcanic rocks.

The trap-rock of Derbyshire was evidently erupted in a state of fusion from some very deep-seated source of intense heat, and intruded between the limestone-beds in three principal currents, now appearing as alternations of trap-rock with sedimentary strata, but which, there is every reason to believe, sprung from one common source, and are lateral protrusions from the great mass of igneous matter. The *toadstone* is a hard rock, consisting of small nodules of white and yellow calcareous spar and green earth, imbedded in a dark greenish paste of basalt. Sometimes the nodules are decomposed, and the stone is then vesicular or cellular, resembling porous lava. The thickness of each of the three distinct beds of this ancient subterranean lava-current interpolated in the mountain-limestone of this district varies from sixty to eighty feet. In some instances, dykes of toadstone traverse the metalliferous veins, and a manifest alteration is then observable in the nature of the latter.†

In some places the elevatory movements have torn the rocks asunder; in others the strata have partially resisted the expansive effect of the erupted lava, and are now in a dome-shaped or arched position, and more or less bent and folded.

Crich Hill, near Matlock affords a highly interesting illustration of this effect of igneous action. It is a dome-shaped hill of mountain-limestone, 800 feet high, consisting of arched strata, enfolding a central mass of trap. This dome of limestone has been forced up through the once superincumbent strata of millstone-grit, which now form a broken and highly inclined wall around it. Such is Crich Hill, a stupendous monu-

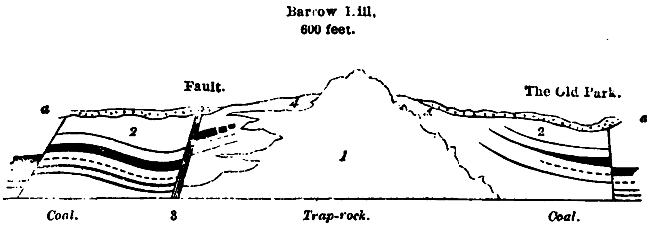
* See Mr. W. Hopkins's "Remarks on Mr. Farey's Account of the Stratification of the Limestone District of Derbyshire," Phil. Mag. 3rd ser. vol. v. p. 121.

† In the cavern at the base of the High Tor in Matlock Dale, a bed of toadstone is seen on the floor, beneath the limestone-strata of which the cliff is composed, and may be traced across the river to the opposite escarpment of Masson's Hill, where it is exposed on the road-side. See Medals of Creation, vol. ii. p. 876.

ment of one of the past revolutions of the globe,—with its arches of rifted rock teeming with mineral veins, and resting on a central mound of molten rock now cooled down into an amorphous mass of compact basalt.*

A dyke of the volcanic rock called green-stone, in some places eighteen yards wide, and which has been traced nearly seventy miles, traverses the Newcastle coal-measures on Cockfield-fell. The coal at the distance of fifty yards from the dyke is altered in its character, and near its contact with the erupted mass is reduced to half-burnt cinder and sooty coaly matter. Wherever trap traverses coal-deposits, more or less change is always observable in the carbonaceous materials.

18. FAULTS IN THE COAL-MEASURES.—In illustration of the displacements called faults, in carboniferous strata,



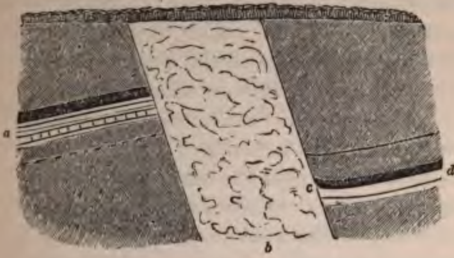
LIGN. 160.—ERUPTED TRAP-ROCK, IN THE DUDLEY COAL-FIELD.
(*Sir R. I. Murchison's Sil. Syst. pl. 37, fig. 1.*)

a, a, Alluvial soil.
1. Erupted Trap-rock.
2, 2. Coal-measures.
3. Barrow Fault: upcast of 90 yards.
4, 4. Coal, charred and altered from contact with the Trap.

I shall select a remarkable one that occurs in the Dudley Coal-field, near Barrow Hill (*Lign.* 160). The central mass of erupted trap that occasioned the dislocation rises to the surface, and forms the summit of Barrow Hill, which has an elevation of about 600 feet. The displacements of the strata on each side of the volcanic rock have produced two lines of fault: and the coal in contact with the igneous rock, as is usual under such circumstances, is charred, and deprived of its bituminous quality.

* See Medals of Creation, p. 890.

In the principal fault, the coal-beds are rent asunder to an extent of 140 yards; and in the part represented in the sketch (*Lign.* 161), the erupted mass (*b*) has upcast the strata on the south-east ninety yards (*a*); the sides of the fissure being inclined from eighty to ninety degrees; thus the group of strata, *a*, *d*, which were originally continuous and



Trap.

LIGN. 161.—SECTION OF A FAULT IN THE DUDLEY COAL-FIELD, NEAR BARROW HILL. (*Sil. Syst.* p. 504.)

a, *d*, Carboniferous strata: the black line denotes the main bed of coal; *b*, Intruded Trap; *c*, the upward twist of the bed of coal *d*, where in contact with the Trap-dike.

horizontal, have been separated, and the edges of the lower portion twisted upwards, as is shown at *c*, by the intruded trap. These carboniferous strata are superimposed on red conglomerate. We shall have again occasion to notice the displacements in the Dudley Coal-field, when treating of the trappean ridges of that part of England.

The faults and dislocations of the strata are so numerous in many coal-fields, that they have been very aptly compared by Dr. Buckland to a fractured sheet of ice:—" If we suppose a thick sheet of ice to be broken into fragments of irregular area, and these fragments again united after receiving a slight degree of irregular inclination to the plane of the original sheet, the reunited fragments of ice will represent the appearance of the broken masses or sheets of coal-measures. The intervening portions of more recent ice, by which they are held together, represent the clay and rubbish that fill the faults, and form the partition-walls that insulate these adjacent portions of strata, which were originally formed like the sheet of ice, in one continuous plane."*

There is a circumstance connected with the upheaval and disruption of the carboniferous strata, and which is also observable in other loosely aggregated deposits, that demands attention. However great the uprise or downcast of the rocks on one side of a fault, it is seldom that there are any external indications of the displacement visible; as for example in the fault of Barrow above sketched (*Ligns.* 160 and 161).† The removal of the upraised masses has possibly, in some instances, been occasioned by debacles or floods of water that have swept over the surface of the country; but in those cases in which the elevated strata were of great extent, and the displacement involved large areas, it is probable that the removal was effected by the action of the sea, when the rocks were first dislocated and forced upwards, and before they emerged above the waters. In other instances, the disintegration may have taken place during their gradual elevation, in like manner as the removal of the Chalk, and the denudation of the underlying Wealden of the south-east of England, were produced. (See above, vol. i. p. 371.)

19. GEOGRAPHICAL DISTRIBUTION OF THE COAL-MEASURES.—Although the geological map (*Plate* I. p. 474) is on a small scale, it will serve to convey a general idea of the geographical position of the areas occupied by the Carboniferous strata of England. The principal coal-basins are those of Somersetshire, Gloucestershire, North and South Wales,

* Bridgewater Treatise, p. 543.

† Mr. Bakewell has treated this subject with great ability: see chap ix. "On the general removal and disappearance of the coal-strata, raised by faults above the surface of the ground."—*Introduction to Geology*, 5th edit. p. 200.

Dudley, Shropshire, Leicestershire, Lancashire, Nottingham, Derbyshire, Yorkshire, Cumberland, Durham, and Newcastle. In Scotland, we have those of the Forth and Clyde. The central districts of Ireland have extensive coal-deposits; but by far the greater part of the coal of Ireland is anthracitic: there are several coal-basins exclusively of this mineral in five or six counties in the south of the Island.

On the Continent, coal, with limestones and conglomerates, in some instances resembling, in others differing from, the English strata, occur in France, near Boulogne,* Mons, and St. Etienne; in Belgium, at Namur and Liege; † in Germany, Silesia, Moravia, Poland, and in the Carpathian Mountains. The Mountain-limestone tract along the Meuse, in the Netherlands, resembles that of Derbyshire and Monmouthshire, and is of the same age; and the scenery to which it gives rise will remind the English traveller of the banks of the Derwent or the Wye.

In Germany ‡ two great coal-bearing series of rocks of palæozoic age are recognised. The lower of these is the "Younger Granwacke" of the Germans, called also the "Flœtzleerer Sandstein," and is equivalent probably to the millstone-grit, the culm series of Devon, and some part of the Scottish coal-measures. The upper series often rests unconformable on the other, and is known as the "Steinkohlen-formation," and represents the English coal-fields. The Mountain-limestone is termed "Berg-kalk" in Germany, and is divisible into, 1st, schists, full of *Posidonomyæ*, such as are found also in Devonshire and South Scotland; 2nd, Productus-limestones; 3rd, silicious flagstones, or "Kieselschiefer."

* See Mr. Godwin-Austen's Memoirs, Quart. Journ. Geol. Soc., vol. ii. p. 1, and vol. ix. p. 231.

† See Journ. Geol. Soc., vol. xii. pp. 47 and 252.

‡ See Geinitz's "Steinkohlen-Format. Sachsen;" and Murchison and Morris, "On the Palæozoic Rocks of Thuringia," &c., Quart. Geol. Journ. vol. xi.

In many parts of France and Germany there are isolated patches of coal-strata, entirely free from marine fossils, and reposing on granite and other hypogene rocks: they are, however, confined to small areas: as in the Department of the Loire, at Brassac in Silesia, and many other places. All these deposits appear to have been formed in lakes, existing on land-areas skirted by the sea in which the Mountain-limestone was deposited.*

In Central France, the rocks that constitute the eastern boundary of the Limagne d'Auvergne are referable to the Carboniferous period, and present phenomena of a highly interesting character, which were first pointed out by Sir R. Murchison in a memoir "On the Slaty Rocks of the Sichon." †

The mineral structure of the schists of the Sichon, their purple, plum-coloured exterior, and their fracture, combined with the aspect of the sandstones, grits, and conglomerates, give them a character from which few geologists would hesitate to assign them to the greywacke, or most ancient Silurian or Cambrian deposits. But Sir R. Murchison, in 1851, obtained fossils ‡ which prove that these rocks belong to the Carboniferous series: the intrusive porphyries of this tract having been erupted after their deposition. Many of the beds of the coal-field of St. Eloy, near Montaigne, are made up of the detritus of still older schists and their quartz veins. Sir R. Murchison could not positively determine whether this coal-tract, as well as other numerous little coal-deposits that extend along the western side of the Mont Dor into the Cantal, are not of the same date as the carboniferous schists of the Sichon; but he is inclined to think them an upper member of the same group. At all events, the highly dislocated positions of the former, and the manner in which they are wedged in among more ancient rocks, indicate that the great porphyritic eruptions above alluded to took place subsequently to their accumulation.

From this occurrence of Mountain-limestone fossils in strata of such

* For an admirable exposition of the relative positions of land and water during the coal-period, see Mr. Godwin-Austen's Memoir, in the Quart. Journ. Geol. Soc. vol. ix. p. 57, &c. See also "Sil. Syst." p. 148.

† Journ. Geol. Soc., vol. vii. p. 5, &c.

‡ Chonetes, Phillipsia, Orthis, Productus, &c., of Carboniferous *species.*

an antique crystalline aspect, and which are highly dislocated and inclined, and are overlaid unconformably by certain coal-fields of France, it is evident that there must have been a powerful disruption of the older members of the Carboniferous—the Mountain-limestone with its shales and sandstones—before the superimposed coal-bearing deposits were accumulated. This fact is of the highest importance in a palæontological point of view, since it proves that the distribution of animal life and the chronology of ancient races do not necessarily accord with the former physical revolutions of the earth's surface. This phenomenon is in accordance with that complete and absolute change in the zoology of the Permian and the Trias, although these deposits present scarcely any evidence of mutual unconformability. On the other hand, whilst many of the Permian *Producti* approach closely to Carboniferous types, there has been in many countries a great break between these two latter deposits. In Britain there has been no *general* severance between the lower and upper members of the Carboniferous series, and hence we possess a very full and copious development of all its middle portion.*

In Silesia and Poland the coal-measures are interstratified with shales and sandstones which overlie the Mountain-limestone, as in England and Belgium; but in the Russian Empire the productive coal-beds are situated in the Mountain-limestone, and are unquestionably fluvio-marine; for through a thickness of eight hundred feet, limestones, grits, and shales, abounding in marine shells, alternate with beds of coal, accumulated apparently by driftage.

In the coal-field of Tudela in Asturia, Spain, there are between twenty and thirty seams of coal. The beds are thrown up into a nearly vertical position, at an angle of about 80° with the horizon. The strata constitute a hill about 400 feet high, and stretching from east to west a mile, and a half from north to south.

20. Carboniferous system of North America.—In North America, the Carboniferous system is largely developed, and has been ably illustrated by Professors Silliman, Eaton, Hitchcock, Rogers, Owen, and other geologists. The stone-coal, or *Anthracite*, of Pennsylvania is associated

* *Op. cit.* p. 8.

with conglomerates, sandstones, and argillaceous shale; and the conglomerates are composed of quartz-pebbles like those of our Old Red Sandstone. Deposits of anthracite exist in Worcester and in Rhode Island, of which an admirable account has been published by Professor Silliman.

Extensive coal-fields are found to the west of the Alleghany Mountains, towards the Mississippi; and the base of the whole extent of the plain of that mighty river appears to be Carboniferous Limestone, the strata of which rest against the Alleghany Mountains on the east, underlie the sand-plains on the west, and, with the lower palæozoic rocks, are upturned on the flanks of the Rocky Mountains at Fort Laramie.* The uppermost layer of the Mountain-limestone supports strata of bituminous coal and shale. Iron-stone abounds in these deposits; and mines of lead occur over a district of two hundred square miles, in the States of Missouri and Illinois.† The principal coal-fields in the United States are the Appalachian, the Illinois, the Arkansas, and the Michigan; the Appalachian, with a computed superficial area of 63,000 square miles, is 726 miles long, and in many parts 180 wide, exclusive of detached anthracitic basins to the eastward: the Great Western, or Illinois,‡ is much more extensive, and has an area as large as England.

The Appalachian coal-field, before its original limits were reduced by denudation, is computed to have been 900 miles long and 200 wide. The thickness of the Carboniferous strata in Virginia and Western Pennsylvania exceeds 3000 feet.§ A large portion of the coal is in the state of *anthracite*, or stone-coal, generally resulting from the influence of subterranean high temperature at former periods. For the most part, the bituminous coal is that which is farthest re-

* Marcou's Geol. Map. † Smart's Travels in the United States.

‡ Dale Owen's Geol. Survey of Wisconsin, Iowa, &c.; Lyell and Hall' Report on the New York Exhibition.

§ *Professor* H. D. Rogers' Address, May, 1844.

moved from the axis of the greatest disturbance, and where the strata have suffered the last displacement. In the coal-fields where the boldest flexures of the Appalachian chain occur, and the strata have actually been overturned, as near Pottsville, the coal is invariably changed into anthracite.*

The Carboniferous system of the United States presents all the essential characters of that of England. The coal-fields are rich in iron-ores; and the same prevalence of *Stigmariæ* in the underclay of the coal-beds occurs as constantly as in the European coal-fields. Thus in the coal-mines of Blossberg, Pennsylvania, the underclays contain Stigmariæ with their rootlets extending in all directions, as in the underclays of the Welsh coal-measures 3000 miles distant.† At Pottsville, where the coal-strata are vertical and worked in the open air, the same phenomenon appears. Several of the coal-seams, from eight to ten feet thick, having been removed, a void space was left, and in the wall on one side, corresponding to the roof, were shales full of ferns, lepidodendra, calamites, &c.; while the other side of the trench was formed of the underclay, abounding in Stigmariæ. These phenomena lead to conclusions respecting the origin of coal from plants not drifted, but growing on the spot. But throughout some of the beds of underclay leaves of fern are plentifully dispersed, though the Stigmariæ are apparently imbedded in their natural position.‡ Limestone of marine origin is more common in the American coal-fields than in those of England; and at Frostburg § a bed of black bituminous shale, ten or twelve feet thick, full of marine shells, is interstratified with the coal.

The Mountain-limestone is thin under the Appalachian or Alleghany coal-field; and in Pennsylvania it is represented by red shale and sandstone, with thin limestones, and yielding valuable carbonates of iron; it is thicker to the south and west, sometimes dolomitic, and is occasionally (Southern Illinois) rich with lead-ores.

In Nova Scotia and Cape Breton, the Carboniferous formation is composed of (1.) an upper and (2.) a lower series

* See the section of the country between the Atlantic and the Mississippi, through the Alleghanies, in Lyell's Travels in North America, vol. i. p. 92: and the admirable geological map of the United States, by Prof. H. D. Rogers, in Keith Johnson's "Physical Atlas."

† Lyell, ibid. pp. 62 and 84. ‡ *Ibid.* vol. ii. p. 18. § Ibid. p. 19.

of coal-measures, and (3.) the Carboniferous Limestone, associated with gypsum, marls, and sandstones.*

The Carboniferous Limestone has also been recognised in the Arctic Regions,† South America,‡ Northern India,§ and probably in Australia.‖

Coal of New Zealand.—The coal found in the north and middle Islands of New Zealand is lignite, more or less compact, and referable to tertiary formations, according to the observations of Dr. Dieffenbach, Mr. Walter Mantell, Dr. C. Forbes, and others. But, according to a communication from Mr. William Lyon to the author, coal of a more ancient period exists about thirty miles from Christchurch, in the valley of the Selwyn. The Canterbury district, from Timaru to Waipara, is in many places bordered by a series of low undulating downs, resting upon the rugged ancient rocks which form the vast boundary-line of the settlement. It is in that portion of these downs known as the Malvern Hills that the coal-formation occurs. It consists of the usual series of limestones, sandstones, clays more or less indurated and laminated, bituminous shales, seams of coal and clay, ironstone, &c., which usually constitute the coal-measures. The limestone is the highest bed seen cropping out; it is fossiliferous, of a superior quality, and at least sixty feet in thickness: separated from this by sandstones and shales, lies the main seam of coal; the first seam is four; the one beneath, six feet in thickness. The associated rocks contain seams of clay-ironstone, one of them abounding in fresh-water shells—*unicnes* (?). The laminated clays and shales contain impressions of stems and leaves

* See Prof. Dawson's "Acadian Geology," 1855.

† Sir E. Belcher, "Arctic Voyage," 1855; Appendix.

‡ A. D'Orbigny, Voyage dans l'Amér. Mérid. vol. iii. p. 231.

§ Dr. A. Fleming, Quart. Journ. Geol. Soc. vol. ix. p. 293.

‖ See the Works of Strzelecki, Darwin, Jukes, M'Coy, Clarke, Stutchbury, &c.

of ferns, apparently of the genera *Pecopteris* and *Sphenopteris.*

21. Organic remains of the Carboniferous System. —The fossils entombed in these deposits comprise numerous genera and species. The animal remains are principally found in the calcareous and arenaceous strata, and are referable to zoophyta, radiaria, crustacea, mollusca, and fishes: and numerous undoubted relics of the reptilian order have been discovered. The vegetable fossils, besides constituting the entire mass of the coal, anthracite, &c., are thickly interspersed in the shales, grits, and other intervening deposits. The shells in the shales of the coal-measures are generally such as are now represented by species living in fresh or estuarine waters; that is, forms related to the Unio, Mytilus, &c.: but there are intercalated beds of marine shells in some localities; as, for example, in Coalbrook Dale. In the northward extension of the Mountain-limestone of Britain, there are intercalations of fresh-water deposits among the limestones and shales which are full of marine shells; and some of the carboniferous deposits of Linlithgowshire are said to be traceable from the fresh-water into the marine condition.*

But the grand features of the Carboniferous system are the immense accumulations of the early vegetation of our globe, presenting to us, in the most legible and striking characters, the peculiar flora of the remote epoch in which these deposits were produced. To obtain any satisfactory results from an examination of these remains, some know-

* Mr. A. Taylor exhibited and explained before the Royal Physical Society of Edinburgh, January 28, 1857, a section in the Bathgate Hills, from Dechmont Laws to Balbardie House, in which a limestone, containing fresh-water fossils, and equivalent to the one worked at Burdie House, is seen gradually to merge into another limestone, containing marine fossils, which is usually recognised as the lowest bed of the Carboniferous series.—*Edinb. New Phil. Journ.* new ser. vol. vi. p. 165.

the internal structure of vegetables is requisite; for sil state many of the external characters are. for the part, so imperfect or obliterated, as to afford but ob- indications of the nature of the original. As in our tigations of the fossil remains of animals we availed elves of the principles of comparative anatomy to recon- ct those extinct forms of being, in like manner we must call to our aid that branch of science which treats of getable organization; we shall thus be enabled to restore ew the forests of extinct tree-ferns and coniferæ, the jun- es of calamites, and all the luxuriant vegetation which ourished during the Carboniferous epoch. I must, how- ever, restrict myself to a brief enunciation of a few leading botanical principles.* The works of Adolphe Brongniart† and of Lindley and Hutton,‡ together with those of Corda, Unger, Goeppert, Hooker, Henslow, Balfour, and Henfrey, should be consulted by those who would pursue this attrac- tive department of natural history.

22. Organization of Vegetables.—In the previous discourse, the complex organization of the higher orders of animal existence was remarked; the structure of vegetables, on the contrary, presents a remarkable simplicity. While in most animals each separate function is effected by an or- gan of peculiar construction, in plants a few tissues, vari- ously modified, constitute the mechanism by which all the vegetable functions are performed. The section of any liv- ing plant shows that its intimate structure is made up of cells or vessels (see also p. 609).§ This organization is dif-

* See Medals of Creation, vol. i. chapters 4, 5, and 6.

† Histoire des Végétaux Fossiles, ou Recherches Botaniques et Géo- logiques, &c., par M. Adolphe Brongniart.

‡ The Fossil Flora of Great Britain, by Dr. Lindley and W. Hutton.

§ Every vegetable cell is the result of the development of a minu granular body or nucleus, on the surface of which a transparent vesi ...ding out so as to form a cell, which, afterwards expand ferently arranged in the grand classes of the vegetable kingdom.* In the most simple group, the *cellulares*, called also the *acotyledones*, from the absence of *cotyledons*, or seed-lobes, the tissue is wholly cellular, the cells being nearly of equal size and consistence; mosses, lichens, sea-weeds, fungi, &c., are examples. These plants have no flowers, and hence are named *cryptogamia*. The vegetables belonging to the other great class are termed *vasculares*, from their cellular tissue being more complex, and assuming the structure of tubes and vessels; and *phanerogamic*, from their bearing flowers. Their tissue is composed of cells of various sizes and forms, and of straight and spiral tubes. This class is subdivided into two families, viz. the *monocotyledonous*, so named from the seed having but one fleshy lobe, or *cotyledon* (*Lign.* 162, *fig.* 5), as the onion, lily, &c., and which are also called *endogenous* (*growing from within*), because increase takes place from the innermost part of the stem; and the *dicotyledonous*, whose seeds have two lobes (*fig.* 4), as the bean, almond, &c.; these are likewise termed *exogenous*, from the new matter being added externally to the old layers, and thus forming annual circles of increase, as in the oak, elm, &c. (*fig.* 8). A transverse section of the monocotyledonous stems (as the cane, palm, &c.) presents, therefore, openings of tubes, which are condensed towards the outer surface (*fig.* 7); while that of the dicotyledonous exhibits annular lines of growth, with diverging rays and a central pith (*fig.* 8); the

more in particular parts, acquires the peculiar form which characterizes the texture to be fabricated. The chemical composition of this elementary structure is identical with starch. In every vegetable, whether the oak or the fungus, this primitive membrane presents the same character; and all the beautiful and apparently complicated tissues of vegetables are but modifications and expansions of these simple elementary nucleated vesicles.

* See Pict. Atlas, Supplem. Notes, p. 175, &c., for a sketch of the history of Fossil Botany, with an outline of Ad. Brongniart's Classification of Fossil Plants, derived from the "Mém. Mus. Nat. Hist." 1822.

latter character is of peculiar importance, because all other classes are destitute of a central cellular column.

In some groups of dicotyledonous trees the elongated c[...] or wood-fibres, are studded with minute pits or transpa[...] spots (*fig.* 6); and this is particularly the case in the C[...] *feræ*, or *cone-bearing* trees; so called from the fruit bei[...]

LIGN. 162.—ILLUSTRATIONS OF VEGETABLE STRUCTURE.

Fig. 1. Cross-section of a coniferous tree, showing the concentric and radiated structure.
2. Longitudinal section of a fragment of pine-wood, highly magnified to exhibit th[...] spotted fibres.
Longitudinal section of two fibres of an Araucaria, highly magnified to show th[...] spots arranged alternately.
4. A dicotyledonous seed split open; the germ is seen in the middle.
5. Section of a monocotyledonous seed, with the germ below.
6. Dotted fibres of coniferous wood.
7. Transverse section of a monocotyledonous stem.
8. Transverse section of a dicotyledonous tree, showing concentric circles, medulla[...] rays, and the central pith.

the form of a cone, as in the pine, fir, &c. Transverse se[...] *tions of* the stems of these trees show the concentric laye[...]

or annular rings, and radiated structure peculiar to the dicotyledonous class. All the trees of this order secrete resin, have branched trunks, and linear, rigid, entire leaves: species are found in the coldest as well as in the hottest regions. In this magnified view of a slice of the common fir (*fig.* 2), the pits are seen to be arranged in double parallel lines. In a remarkable family of pines, the *Araucariæ*, these little spots are placed alternately, and sometimes in triple rows. The *Araucaria* is a native of and peculiar to Norfolk Island, in the South Pacific. This small island, which is only about fifteen miles in circumference, presents a scene of the most luxuriant vegetation, and abounds with this particular group of pines, some of which attain a height of two hundred feet, and a circumference of thirty.

In the Royal Botanic Garden of the University of Breslau is a fossil stem of the *Pinites protolarix* (from the Brown-coal of Laasan in Silesia), which is thirty-six feet in circumference, which is reputed to have possessed between 4000 and 5000 annual rings! (Gœppert. See p. 671). The living *Wellingtonia* or *Sequoia gigantea* has a height of three hundred feet, and a diameter of from twenty to thirty feet.

Even in the foliage of the different families of plants, there are such obvious distinctive characters that the botanist can often from a mere fragment of a leaf detect the dicotyledónous structure in the reticulated nervation of a leaf, as in that of the oak; and the monocotyledonous, in the smooth parallel veins in that of the lily. The application of these principles to the investigation of the fossil remains of vegetables we may now consider.

23. Climate and Seasons indicated by Fossil Wood.—In the course of these Lectures, it has been demonstrated how, by a knowledge of comparative anatomy, the form, structure, and economy of beings long since obliterated from the face of the earth may with certainty be determined; *in like manner*, by the aid derived from a

few botanical principles, we may not only discover the form and character of vegetables of which but the faintest vestiges remain, but also point out important inferences relating to the state of the earth, the nature of the climate, and even of the seasons which prevailed at the periods when those plants flourished. Mr. Babbage has admirably exemplified the inductive process by which such results may be obtained:—

"We have seen that dicotyledonous trees increase in size by the deposition of an additional layer annually between the wood and the bark; and that a transverse section of such trees presents the appearance of a series of nearly concentric irregular rings, the number of which indicates the age of the tree. The relative thickness of these annular markings depends on the more or less flourishing state of the plant during the years in which they were formed. Each ring may, in some trees, be observed to be subdivided into others, thus indicating successive periods of the same year during which its vegetation was advanced or checked. These rings are disturbed in certain parts by irregularities resulting from branches; and the year in which each branch first sprang from the parent stock may therefore be ascertained by proper sections. These prominent effects are obvious to our senses; but every shower that falls, every change of temperature that occurs, and every wind that blows, leaves on the vegetable world the traces of its passage; slight, indeed, and imperceptible perhaps to us, but not the less permanently recorded in the depths of those woody fabrics.

"All these indications of the growth of the living tree are preserved in the fossil trunk, and with them also frequently the history of its partial decay. Let us now examine the use we can make of these details relative to individual trees, when considering forests submerged by seas, imbedded in peat-mosses, or transformed, as in some of the harder strata, into stone. Let us imagine that we possessed sections of the trunks of a considerable number of trees, such as those occurring in the stratum called the *Dirt-bed* in the Island of Portland.* If we were to select a number of trees of about the same size, we should possibly find many of them to have been contemporaries. This fact would be rendered probable, if we observed, as we doubtless should do, on examining the annual rings, that some of them, conspicuous for their size, occurred at the same distances of years in several trees. If, for example, we found on several trees a remarkably large annual ring, followed at the distance of

* See above, vol. i. p. 398.

seven years by a remarkably thin ring, and this again, after two years, succeeded by another large ring, we should reasonably infer from these trees, that, seven years after a season highly favourable to their growth, there had occurred a season unfavourable to them; and that after two more years, another very favourable season had happened; and that all the trees so observed had existed at the same period of time. The nature of the season, whether hot or cold, wet or dry, would be known with some degree of probability, from the class of tree under examination. This kind of evidence, though slight at first, receives additional and great confirmation by the discovery of every new ring which supports it; and, by a considerable concurrence of such observations, the succession of seasons might be ascertained in geological periods, however minute."

24. MICROSCOPIC EXAMINATION OF FOSSIL TREES.*— The discovery of a process by which the structure of fossil vegetables can be examined with as much facility as that of recent plants, has shed an unexpected light on the ancient botany of our planet. On this plate of glass you perceive a thin film of a dark substance, apparently of varnish. It is a slice of the blackest jet; and, if held between the eye and the light, appears of a rich brown colour, and displays a ligneous structure, resembling that of deal or fir: it is, in fact, a thin section of fossil coniferous wood; for jet is nothing more than the wood of some species of fir or pine, that has undergone the process of bituminization, as I shall presently explain. When viewed under a microscope, the small pittings, which I have mentioned as peculiar to the *Coniferæ* (*Lign.* 162, *figs.* 2 and 3), are distinctly visible. The other specimens before us are silicified woods, prepared in the same manner. A few words in explanation of the mode by which sections of such extreme thinness are obtained may not be uninteresting. A slice is first cut from the fossil wood by the usual process of the lapidary; one surface is ground perfectly flat, and polished, and then cemented to a piece of plate-glass by means of Canada-balsam; the slice thus firmly attached to the glass is next ground down to the requisite

* *Medals of Creation*, vol. i. p. 65.

degree of tenuity, so as to permit its structure to be s
by the aid of the microscope. It is by this ingenious ;
cess that the intricate structure of any fossil plant can 1
be investigated, and the nature of the original determi
with as much accuracy as if it were recent.*

A method discovered by Dr. Franz Schulz, of detecting the inte vegetable structure in lignite, coal, anthracite, &c., consists in treatin coal with nitric acid in a platinum-vessel, and then evaporating the by a moderate heat, and igniting the residue until no further empy matic vapours are given off; the residue is submitted to the actio nitric acid, and the ignition repeated. Thus prepared, the coal is pl in a platinum-crucible with a lid perforated in the centre, and air is bl from a gasometer through the aperture in the lid, while the crucibl kept at a red heat over a spirit-lamp, so that the coal is slowly c sumed. The ash thus obtained is not in the state of coke, as would the case in the ordinary method of incineration, but forms a brown p der full of white splinters. These splinters, on microscopical exan ation, are found to be the silicious cellular structure of the orig vegetable. By this process vegetable tissue has been detected in *anthracite* or stone-coal of Pennsylvania, by Dr. Baily.†

The experiments and observations on the structure of plants by Rev. J. B. Reade have brought to light some interesting facts in illus tion of this subject. Mr. Reade states that "by the agency of heat surrounding silicious matter may be liquefied, and the carbon and g eous products of the wood dispelled, while the essential characters of fibrous and cellular structure are undisturbed. The unconsumed] tions, which alone constitute the true vegetable frame-work, are thus it were, mounted in the fluid silica. This property of vegetable fibr retaining its form, notwithstanding the action of a high temperature, s gested to me the probability of detecting structure in the ashes of c and upon examination, I found that the white ashes of 'slaty coal' nish most beautiful examples of vegetable remains." In a subseq paper the author adds the following remarks:—"Having ascerta

* See H. Witham's "Observations on Fossil Vegetables," with p of the internal structure of plants; also Prof. J. Quekett's "Histolo Lectures," and "Histol. Catal. Roy. Coll. Surgeons;" Alex. Brys paper on Preparing Fossils for Microscopic Investigation, Edinb. Phil. Journ. N. S. vol. iii. p. 297; and Dr. Carpenter's *Microscope*.

† American Journal of Science, 2nd series, vol. ii. p. 124.

that the silicious organization of recent plants is not destructible, even under the blow-pipe, it appeared to me a natural inference, that the less intense heat of a common fire would not destroy this silicious tissue in the coal-plants; and my opinion has been confirmed, for I have detected in the white ashes of coal all the usual forms of vegetable structure, viz. cellular tissue, smooth and spiral fibre, and annular ducts. A comparison of the ashes of coal with those of recent plants would doubtless afford some further insight into the nature of fossil vegetables. To mention only one instance,—I have ascertained that the lumps of carbonized matter which occur abundantly in the Upper Sandstone near the Spa at Scarborough are, in all probability, portions of the stems of some arundinaceous or gramineous plants. The structure of the epidermis is precisely similar to that of the oat, consisting of parallel columns, set with fine teeth, dove-tailing, as it were, into each other, while the underlying tissue consists of cubical cells, a thin horizontal section exhibiting a series of squares. From these facts it is evident, that the true framework and basis of vegetable structure in the plants of coal is not only entirely independent of carbon, but that it has also resisted the bituminous decomposition which has converted all the carbonaceous materials into a highly inflammable substance." *

Another plan for facilitating the microscopical examination of coal is as follows: †—Soak the coal or lignite in a saturated solution of carbonate of soda for from ten to fourteen days, when it will be much softened, and fine slices may be cut from it with a razor or scalpel; place the slices in strong nitric acid, until they become somewhat bleached; use them without delay, and, if desirous of preserving the preparations, mount them in glycerine.

Prof. Morris recommends a ready mode of preparing coal for examination,—boiling the small fragments in nitric acid, washing, and examining them at once.

25. NATURE OF COAL.—In this stage of our inquiry the nature of the process by which vegetables are converted into the mineral substance termed *Coal* requires additional consideration.

Under the microscope a thin slice of true coal exhibits minute, yellowish, semi-transparent particles, with an intermediate deep-brown substance. The amber-coloured material is of a bituminous nature, and so volatile

* Journal of Science, vol. ii. p. 413.

† *For the explanation of this* method, the Editor is indebted to Prof. *Henfrey. See also Micrograph. Dict.*

as to be readily expelled by heat before the texture of the coal is destroyed. When the slice is taken in one direction, the yellow particles are seen to be elongated; when cut at right angles, minute circular cross-sections of these bituminous bodies are observed, appearing like cells packed closely together. The intermediate brown substance consists of vegetable fibres and earthy matter. The lengthening out of the component yellow particles is evidently due to the compression of layer on layer of the carbonaceous matter; hence the readiness with which coal usually breaks into cubical masses; the line of fracture passing between and parallel with the compressed particles on four sides of the cube, and across them at right angles to their length, on the other two sides of the cube. The same rule is necessarily followed in the cleavage of every substance containing either elongated particles or elongated cavities,—whether it be clay-slate or mica-schist, timber or pie-crust.

The yellow bituminous particles in the coal are the chemical result of the decomposition of the old vegetable matter, consisting of the loose woody and pithy tissue, chiefly of *Sigillariæ*, *Lepidodendra*, and *Calamites*, which formed the great swamp-jungles of the coal-period. Layer after layer of these dead trees accumulated as swampy peat, intermingled here and there with tree-ferns and coniferous trees, brought from higher ground by floods and freshets, and occasionally overlaid by sand- and clay-beds; and the pulpy mass of black carbonaceous mud, similar to what may now be found at the mouths of the tropical rivers and in the swamps of the Mississippi, underwent those gradations of change which converted the woody fibre of the plants into the hydrocarbon of the coal. Hence the endless varieties of cannel-coal and ordinary coal. The former not unfrequently contains the remains of *Anthracosiæ*, *Myalinæ*, and Fishes, and, at Pictou, of Reptiles. Cannel-coal has more earthy and animal matter than common coal contains; and frequently alternations of thin layers of earthy cannel and bright black bituminous coal are observable in common coal.

The Boghead or Torbane Hill coal ("Bitumenite" of Dr. Trail) appears to be a modification of the usual form of cannel-coal; the constituent bituminous particles being larger, less compressed, and more radiated in their inner structure. The "Albertite," found at Hillsborough, New-Brunswick, is still more bituminous, and is amorphous in its composition.

In the dust and the ashes of coals fragments of reticulated and dotted tissue, and of pitted fibres, may be readily found, forming interesting microscopical objects. The scalariform tissue of Sigillaria is not unfrequent in the cannel-coals. Even in the anthracite or stone-coal of North America, which is a hard slaty rock, the vascular tissue may be rendered distinctly visible.

The best specimens of pitted fibre (coniferous wood) are obtained from the dusty charcoal-like substance often seen on fresh surfaces of coal. This "mother-charcoal" is supposed to be the relics of the drifted conifers, the wood of which appears not to have readily mingled with the swamp-peat.*

Mr. Parkinson, whose work on Organic Remains abounds in interesting observations and experiments on the fossilization of vegetable substances, has argued, that the formation of coal has depended upon a change which all vegetable matter undergoes when exposed to heat and moisture, under circumstances that exclude the air, and prevent the escape of the more volatile principles.† In this condition, a fermentation, which he terms the bituminous, takes place, of which the phenomenon exhibited by *mow-burnt hay* is a familiar example. The production of sugar, and, by continuance of the process, of vinegar, is effected by ve-

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* Besides the works of Lyell already alluded to, and De la Beche's "Geolog. Observer," and other general treatises, especially Prof. Ansted's "Elem. Course of Geology," &c., the student is especially referred, for the consideration of the nature and structure of coal, to the following works: Dr. Redfern "On the Nature of the Torbane Hill and other Varieties of Coal," Quart. Journ. Microsc. Science, vol. iii. p. 106; Prof. Balfour "On the Structure of Coal," Annals Nat. Hist. 2nd ser. vol. xiv. p. 229; Prof. Quekett "On the Intimate Structure of a Peculiar Combustible Mineral from the Coal-measures of Torbane Hill, near Bathgate, Linlithgowshire," Transact. Microsc. Soc. N. S. vol. ii. p. 34; Dr. Hooker "On the Vegetation of the Coal-period," Mem. Geol. Survey, vol. ii. part 2; Prof. Harkness "On Coal," Edinb. N. Ph. Journ. vol. lvii. p. 66, and "On Mineral Charcoal," *ib.* N. S. vol. i. p. 73; Prof. J. W. Dawson "On the Coal-measures of the South Joggins," Quart. Journ. Geol. Soc. vol. x. p. 1; Mr. G. Tate's "Fossil Flora of the Mountain-Limestone Formation of the Eastern Borders;" and his papers on the subject in the Trans. Berwicksh. Nat. Field-club, vol. iii. pp. 134, 195, and 218; and Mr. Newberry "On Cannel-coal," Americ. Journ. Science, 2nd ser. vol. xxiii. p. 212, and Edinb. N. Ph. Journ. N. S. vol. v. p. 364 and vol. vi. p. 368.

Many valuable remarks on the similarity of physical and chemical conditions exhibited by peat-moss, lignite, and coal are to be found in the "Essays on the Natural History and Origin of Peat-moss," by the Rev. R. Rennie, 8vo, Edinburgh, 1810; and also in Leo Lesquereux's Memoir in the Bullet. Soc. Sc. Nat. Neuchâtel, vol. i. p. 471, and Quart. Journ. Geol. Soc. vol. *iv. part 2,* Miscell. p. 30.

† *Organic Remains of a Former World,* vol. i. p. 181.

getable fermentation in the open air. In the process of hay-making, the saccharine fermentation is induced, and the grass acquires a peculiar fragrance and sweetness; but in wet seasons, when the hay is prematurely heaped together, the volatile principles cannot escape from the inner mass of vegetable matter, heat is rapidly evolved, a dense vapour exhales, and at length flames break forth, and the stack is consumed. When the process is interrupted, and combustion prevented, the hay is found to have acquired a dark-brown colour, a glazed or oily surface, and a bituminous odour. Were vegetable substances, under the circumstances here described, placed beneath great pressure, so as to confine the gaseou elements, bitumen, lignite, or coal might be produced, according to th various modifications of the process. Vegetable matter is thus trace through every stage of the saccharine, vinous, acetous, and bitumino' fermentations; producing alcohol, ether, naphtha, petroleum, bitume amber, and even the diamond; and explains that by the process of bit minization stems and branches have been converted into brown-co lignite, jet, coal, and anthracite.

According to analyses made at the Museum of Practical Geology the Newcastle coal has a specific gravity, varying from 1.23 to 1.31, a consists of

Carbon	from	78.01	to	85.58
Hydrogen	—	5.04	—	5.56
Nitrogen	—	0.72	—	1.84
Sulphur	—	0.71	—	1.85
Oxygen	—	2.40	—	10.31
Ash	—	2.14	—	9.12

The percentage of coke left by this coal varies from 35.60 to 72.31.

Iron- and copper-pyrites abound in many of the beds of coal; † an indeed, these metallic substances are very generally met with in a cumulations of carbonized vegetables. The carburetted hydrogen, wi the acid and extractive matter, resulting from vegetable decompositio are adequate to produce copper-pyrites, and even metallic copper, fro water holding salts of copper in solution. The pyrites so abundant the Wealden strata of the Isle of Wight, in the Gault, the Kimmerid Clay, the Lias, and other formations has originated from this cause.

Prof. W. B. Rogers has some interesting remarks on the origin a accumulation of the proto-carbonate of iron in coal-measures, in *Sillima*

* The Parliamentary "Reports on the Coals suited to the Steam Navy by Sir De la Beche and Dr. L. Playfair, 1848—51.

† Some observations on the presence of certain metals in coal will found in the Report of the Brit. Assoc. 1856, Sect. p. 51.

Journal,* where he shows that, accompanying the coal-beds, were deposits containing much organic matter, and impregnated with sesquioxide of iron, which by the influence of the changing vegetable matter, and the emitted carburetted hydrogen and carbonic acid, became converted into the protocarbonate. (See p. 767, *note*.)

26. Liebig on the formation of Coal.—The nature of these changes is thus explained by the eminent chemist, Baron Liebig. Vegetable substances after death undergo two processes of decomposition; namely—

1st. *Fermentation* or *decay*, which is a slow process of combustion (*eremacausis*), in which the combustible parts of a plant unite with the oxygen of the atmosphere; for the decay of woody fibre in contact with air or oxygen converts the latter into an equal volume of carbonic acid; the presence of water and a certain temperature being necessary. Woody fibre in a state of decay forms *humus*.

2dly. *Mouldering* or *putrefaction* of wood subjected to the action of water, and more or less excluded from the air. When pure ligneous fibre, as linen, for example, is placed in contact with water, considerable heat is evolved, and the vegetable matter loses its coherence, and becomes a soft friable mass; in short, it undergoes a true putrefaction.

When all access to air is excluded and consequent oxidation and a removal of a certain quantity of hydrogen, then other changes ensue, and true mineral coal containing combustible oils is the result. In deposits of wood-coal changes are still going on, as is proved by the issue, from clefts in the rocks of the coal-formation, of inflammable gases; such as carburetted hydrogen, nitrogen, and olefiant gas. Thus from the continual removal of oxygen, in the form of carbonic acid, from layers of wood-coal, that substance gradually approaches in its composition to mineral coal. From the latter hydrogen is disengaged in the form of a compound (hydro-carbon); and the removal of all the hydrogen gives rise to *anthracite* or stone-coal.†

The chemical changes of this nature, which are continually taking place in carboniferous deposits, give rise to those evolutions of carbonic acid (*choke-damp*) and carburetted hydrogen, or *fire-damp*, which are frequently so fatal to the miners. And it is a fact worthy of remark, as corroborative of the opinions above advanced, that the bituminous quality

* New. Ser. vol. xxi. p. 339.

† Liebig's *Chemistry*, translated by Professor Playfair.

of the coal depends on the nature of the bed which immediately covers it. If this be argillaceous shale, the escape of the gaseous matter of the coal is prevented; but, if the roof be arenaceous, the gas is evolved from the coal, and collects in the innumerable fissures and pores of the sandstone, which become filled with carburetted hydrogen, and form as it were a gasometer, ready to explode upon any occasion. Mr. Hutton is of opinion that this gas exists in a highly condensed, and even liquid, state in the pores of the coal; and that the small explosions (termed by the miners eructations) which often take place when the coal is struck with a pick, are due to the sudden expansion of the condensed gas.*

Carburetted hydrogen obtained artificially from coal, peat, oil, and wood,† is well known as "gas," of which such large supplies are now needed for the lighting of our towns. This gas is thrown out naturally from the coal-deposits of many districts; and is sometimes, under those circumstances, used for economical purposes.‡ The fire-temples of Western Asia were, and still are, supplied from this source; at some salt-works in China, they have long used this inflammable gas in evaporating the brine, and lighting the premises; the town of Fredonia, in New York State, is lighted by means of a local supply of the gas; in the Hepburn Colliery, the gas from the coal is used to light the stables; and at Wallsend, a large quantity of gas (11,000 hogsheads a minute) is brought to the surface by iron pipes, and wasted.

27. BITUMEN, PETROLEUM, NAPHTHA.—The changes effected in vegetable matter during its conversion into coal also give rise to various bituminous productions.

Mineral oil is an inflammable fluid which often occurs in carboniferous deposits, sometimes forming powerful springs. *Naphtha* is another liquid of this nature, which is nearly colourless and transparent, burns with a blue flame, emits a strong odour, and leaves no residuum. In driving a level through coal-shale in Derbyshire, springs of naphtha burst forth, and covered the surface of the water in the level; and, having been accident-

* Sir H. De la Beche, Geological Manual, 3d edit.

† An interesting Report, on the Produce and Value of Wood-gases, is published in the Franklin Institute Journal, No. 380, Aug. 1857, p. 126.

‡ De la Beche's Geol. Observ. p. 409; Tate's Fossil Flora of the Eastern Borders, p. 316. See also Report of Lyell and Faraday, on the *Explosion* at the Haswell Collieries, 8vo, 1844; with Vertical Section of *the Haswell* Colliery, Durham: also other Parliamentary Reports on [illegible]plosions in Collieries, by De la Beche and others.

ally set on fire by the approach of a candle, formed a burning spring, which continued some weeks.

Petroleum is of a dark colour, and thicker than common tar; in the carboniferous strata of Coalbrook Dale, and in some parts of Asia, this substance rises from coal-beds in immense quantities. From a careful analysis of petroleum and certain turpentine-oils, it is clear that their principal component parts are identical; and it therefore appears probable that petroleum has originated from the coniferous trees whose remains have contributed so largely to the formation of coal; and that the mineral-oil is nothing more than the turpentine-oil of the pines of former ages,—not only the wood, but also large accumulations of the needle-like leaves of the pines, may have contributed to this process. We thus have the satisfaction of obtaining, after the lapse of thousands of years, information as to the more intimate composition of those ancient forests of the period of the great coal-formation, whose comparison with the present vegetation of our globe is a subject of so much interest. The mineral oil may be ranked with amber, succinite, and other similar bodies which occur in the strata. The springs of petroleum do not seem to depend on combustion, as has been supposed, but to be simply the effect of subterranean heat. According to the information we now possess, it is not necessary that strata should be at a very great depth beneath the surface to acquire a temperature equal to the boiling point of water or of mineral oil. In such a position the oil must have suffered a slow distillation, and have found its way to the surface; or have so impregnated a portion of the earth, as to form springs or wells, as in various parts of Persia and India.*

Bitumen is an inspissated mineral oil, of a dark-brown colour, with a strong odour of tar. In the Odin mine of Derbyshire, elastic bitumen occurs, being of the consistence of thick jelly, and bearing some resemblance to soft India-rubber; as it will remove the traces of a pencil, it has been named "mineral caoutchouc." Some bitumens possess the colour and transparency of amber: the soft varieties may be rendered solid by heat.

From these bituminous substances, we pass by an easy transition to *Amber*, † of which we have already spoken (p. 245); for "black amber,"

* Dr. Reichenbach. The bituminous products of the border-countries of Turkey and Persia are described by Mr. Loftus, in the Geol. Soc. Journ. vol. xii. p. 269.

† In Liebig's opinion, amber, fossil resin, and mellite are the products of vegetable matter *that has suffered eremacausis* or decay. They are *found in wood or brown-coal*, and have evidently proceeded from the de-

both in its appearance and composition, closely resembles the solid bitumens.

A mineral called *Mellite*, or honey-stone, from its colour, is found among the bituminous wood of Thuringia, and in its chemical composition, and electrical properties, bears a great analogy to amber; it is usually crystallized in small octahedrons.*

28. THE DIAMOND.—The chemical constituents of the substances above described are chiefly carbon and hydrogen, with a small proportion of oxygen, the essential elements of vegetable matter. But the *Diamond* is pure carbon; at a heat less than the melting point of silver, it burns, and is volatilized, yielding the same elementary products as charcoal.

Sir Isaac Newton remarked, that the refractive power, that is, the property of bending the rays of light, was three times greater in respect of their densities in amber and in the diamond than in other bodies; and he therefore concluded that the diamond was some unctuous substance that had crystallized.

Sir David Brewster observed, that the globules of air (or some fluid of low refractive power) occasionally seen in diamonds have communicated, by expansion, a polarizing structure to the parts in immediate contact with the air-bubble, a phenomenon which also occurs in amber. This is displayed in four sectors of polarized light encircling the globule of air; a similar structure can be produced artificially, either in glass or gelatinous masses, by a compressing force propagated circularly from a point. This cannot have been the result of crystallization, but must have arisen from the expansion exerted by the included air on the amber and the diamond, when they were in so soft a state as to be susceptible of compression from a very small force; hence Sir David Brewster concludes that, like amber, the diamond has originated from the consolida-

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composition of substances which were contained in quite a different form in the living plants. They are all distinguished by their proportionably small quantity of hydrogen. The acid from mellite (mellitic acid) contains precisely the same proportions of carbon and oxygen as that from amber (succinic acid); they differ only in the proportion of their hydrogen. Succinic acid may be obtained by oxidation from wax and from all solid fats.—*Liebig's Chemistry*, vol. i. p. 336.

* *Organic* Remains of a Former World, vol. i. pl. i. fig. 2.

tion of vegetable matter, which has gradually acquired a crystalline form by the slow action of corpuscular forces.*

Liebig concurs in the opinion that the diamond is of vegetable origin, and offers the following remarks on its probable mode of formation.

"If we suppose decay to proceed in a liquid containing carbon and hydrogen, then a compound with still more carbon must result, in a manner similar to the production of the crystalline colourless *naphthalin* from a gaseous compound of carbon and hydrogen. And, if the compound thus formed were itself to undergo further decay, the final result must be the separation of carbon in a crystalline form. Science can point to no process capable of accounting for the origin and formation of diamonds, except that of decay. Diamonds cannot have been produced by the action of fire; for a high temperature and the presence of oxygen gas would call into play their combustibility. But there is the greatest reason to believe that they have been formed in the humid way; and the process of decay is the only cause to which their formation can with probability be ascribed." †

By voltaic action the diamond has been converted into a substance possessing the appearance, physical character, and electrical properties of *coke*. In this state the diamond loses its insulating power, and becomes lighter: the specific gravity of an ordinary diamond is 3.368; when changed into coke, 2.679.‡

The diamond in a pure state is colourless and transparent; when coloured, it contains foreign matter, as metallic oxides, &c. A blue diamond (the property of Mr. H. T. Hope), weighing 177 carats, is a splendid and unique specimen of this precious gem. There are pink, orange, yellow, and dark-brown diamonds. The largest-known diamond belongs to the Rajah of Mattan; it is of the purest water, and weighs 367 carats, or (at the rate of four grains to a carat) three ounces troy weight: it is egg-shaped. The Mogul Diamond,§ called the Koh-i-noor, or "mountain of light," weighed when first found 793 carats; when exhibited at the Crystal Palace (1851) it weighed 186 carats; it was recut in 1852, and now weighs 102.

The matrix of the diamonds found in Central and Southern India is a wide-spread conglomerate, overlying the sand-stones, limestones, and gneiss-rocks of the country.

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* Geol. Trans. 2nd ser. vol. iii. p. 459. † Liebig's Chemistry, vol. i. p. 336. ‡ Experiments of M. Jacquelin and Prof. Faraday.

§ See Prof. Tennant's interesting observations on this great diamond, and the probable *history of its* division into three portions, one of which *(the Koh-i-noor) is now* at Windsor Castle; Transactions of the Society *of Arts, 1852, p. 336.*

29. Anthracite, Plumbago, &c.—The coal commonly used for domestic purposes in this country is the bituminous, of which there are many varieties, such as cherry-coal, caking-coal, splint-coal, and cannel-coal.* The *Anthracite*,† culm, or stone-coal, is coal usually deprived of its bitumen by the causes already explained; anthracitic bands, however, occasionally are intercalated with seams of bituminous coal. When coal is near to trap or basalt, it is often in the state of anthracite; while the layers in immediate contact with the volcanic rocks are charred, and in some instances coked; or the mass is converted into *plumbago*, or *graphite*, the substance used for drawing-pencils. By a series of interesting experiments, Dr. Macculloch‡ demonstrated the transitional changes from bitumen to plumbago. Hydrogen predominates in the fluid bitumen; bitumen and carbon in coal; in anthracite, bitumen is altogether wanting; and in plumbago, the hydrogen has also disappeared, and carbon only or chiefly remains.

In North America, from the prevalence of anthracite in the carboniferous deposits, this substance is in nearly universal use; but in England it is seldom employed except in Arnott-stoves and the furnaces of our manufactories.§ This kind of coal is, however, largely developed in many districts; and the anthracite of South Wales extends from the Vale of Neath, on the east, to St. Bride's Bay on the west. Some of this coal is in the state of charcoal, and requires a degree of heat of 531° Fahrenheit, for its ignition; but, when ignited, it burns with a bright flame, and is the most durable of fuel.

30. Petrifaction of Vegetables. —As in the sand-

* See Parliamentary Reports on the coals suited for the steam-navy.

† From the Greek *ανθραξ*, signifying coal or charcoal.

‡ Transact. Geol. Soc. vol. ii. p. 1.

§ The anthracite of the Alleghanies is of very slow combustion; but this is overcome by freely supplying oxygen by means of a blower, even in the fire-places of private dwellings: and the drying effect on the air of the apartments is counteracted by the evaporation of water.

stones and other strata the stems of trees and plants are often found not in the state of coal, but converted into stone —in some instances calcareous, in others silicious, I shall in this place offer a few remarks in illustration of the process by which such a change has been effected.

In true petrifactions a transmutation of the parts of an organized body into mineral matter takes place. Patrin, Brongniart, and other philosophers suppose that petrifaction has frequently been effected suddenly, by the combination of gaseous fluids with the constituent principles of organic structure. It appears, indeed, certain, that the conversion of animal and vegetable substances into silex must, in many instances, have been almost instantaneous; for the most delicate parts, those which would undergo decomposition with the greatest rapidity, are preserved. The occurrence in the Oolite, at Tisbury, of Trigonias, having their delicate branchiæ and other portions of the body preserved in their natural position by silicification (p. 527), illustrates these remarks. So also does the preservation of a zoophyte in agate, as described and figured by Mr. Bowerbank.* The fact of the silicification of trees in loose sand, and of the soft bodies of molluscs in their shells, as in the fossil oysters found in the chalk at Brighton,† while neither the sand nor the shells are impregnated with silex, cannot be explained by the infiltration of a silicious fluid into cavities left by the decomposition and removal of the animal substance.‡ Von Buch has shown that the silicifying process never immediately attacks the calcareous shell, but developes itself only upon the organic matter, and that, where this substance is not present, no silicification takes place. A combination of gaseous fluids with the constituent principles of the animal or vegetable substances, changing the latter into stone without modifying the arrangement of the molecules so as to alter

* Journ. Geol. Soc. vol. v. p. 319. See also *ibid.* p. lxxviii., Anniversary Address by Sir H. De la Beche, for some remarks on this interesting fossil, and on silicification generally.

† Medals of Creation, p. 374.

‡ It still remains for some patient investigator to elucidate the as yet mysterious relations of carbon and silicon, and to recover the broken clue to this research left by the untimely death of Dr. Samuel Brown, of Edinburgh. His early experiments on the transmutation of these two substances appear to have been followed in later years by more certain results, which, however, this lamented chemist had not published at the time of his death. *See the deeply* interesting article on Dr. S. Brown *and Prof. E. Forbes, in the* North British Review, February, 1857.

the external form, seems the only mode by which such transmutations can have been effected. The production of congelation, by a simple abstraction of caloric, is akin to this change; but petrifaction is induced by the introduction of another principle. As to density, the most subtle gas may acquire the greatest solidity; as, for example, in the union of oxygen with metallic substances.

The following remarks, selected from Mr. C. Stokes's observations * on fossil wood and plants, throw light on this subject. The specimen which gave rise to these remarks was a piece of beech-wood, partly petrified by carbonate of lime, from a Roman aqueduct in Germany. In this wood were several insulated portions converted into carbonate of lime, while the remainder was unchanged.

Sometimes the most minute structure is preserved, as in the vessels of palms and coniferæ, which are as distinct in the fossil as in the recent trees. From this state of perfection, we have every degree of change, to the last stage of decay: the condition of the wood, therefore, had no influence on the process. The hardest wood, and the most tender and succulent, as, for instance, the young leaves of the palm, are alike silicified. In some instances, the cellular tissue has been petrified, and the vessels have disappeared; here silicification must have taken place soon after the wood was exposed to the action of moisture, because the cellular structure would soon decay; the process was then suspended, and the vessels decomposed. In other examples, the vessels alone remain; a proof that petrifaction did not commence until the cellular tissue was destroyed. The specimens where both cells and vessels are silicified show that the process began at an early period, and continued until the whole vegetable structure was transmuted into stone.

In a morass near Ferry-bridge, in Yorkshire, a similar partial petrifaction of the stems and branches of trees has taken place.†

The late Dr. Turner, in some admirable comments on the subject of petrifaction, remarked, that, whenever the decomposition of an organic body has begun, the elements into which it is resolved are in a condition peculiarly favourable to their entering into new combinations; and that, if water, charged with mineral matter, come in contact with bodies in this state, a mutual action takes place, new combinations result, and solid

* *Transactions* of the Geological Society, 2nd ser. vol. v. p. 212.

† Described by Mr. Stokes, op. cit. p. 211.

particles are precipitated, so as to occupy the place left vacant by the decomposed organic substance.

31. ARTIFICIAL VEGETABLE PETRIFACTIONS.—Prof. Göppert has published the result of an interesting investigation of the condition of fossil plants, and the process of petrifaction. Layers of ironstone-nodules, as we have previously stated, are common in the carboniferous strata. They appear to have once constituted continuous layers, the nodules having been produced by segregation, *i. e.* the substance of which they are composed has separated from the constituent parts of the rock after deposition.* The first segregation often appears to have been caused by the presence of some extraneous matter, sometimes a trilobite or a shell, and very commonly the leaf of a fern.† Parkinson had remarked, that the leaves in these nodules might sometimes be separated in the form of a carbonaceous film; and Göppert, having found similar examples, was induced to undertake a set of experiments. He placed fern-leaves in clay, dried them in the shade, exposed them to a red heat, and obtained striking resemblances to the fossil plants. According to the degree of heat, the plant was found to be either brown, shining black, or entirely lost, the impression only remaining; but in the latter case the surrounding clay was stained black, thus indicating that the colour of the coal-shales is from the carbon derived from the plants they include. Plants soaked in a solution of sulphate of iron were dried and heated until every trace of organic matter had disappeared, and the oxide was found to present the form of the plant. In a slice of pine-tree the pitted fibres peculiar to this family of vegetables were perceptible. These results by heat are probably produced naturally, by the action of moisture under great pressure, and the influence of a high temperature.‡

* Sir H. De la Beche, Researches in Theoretical Geology, p. 96.
† *Medals of Creation*, p. 69 and p. 522.
‡ *Quart. Journ. Geol. Soc.* vol. vi. part 2, Miscell. p. 33.

32. SILICIFICATION OR PETRIFACTION OF VEGETABLES BY SILEX.—The various forms in which silex is found have been probably dependent on its state of solution; in the case of quartz-crystals it was entirely dissolved; in agate and chalcedony it is supposed to have been in a gelatinous state, assuming a spheroidal or orbicular disposition, according to the motion given to its molecules. Its condition appears also to have been modified by the influence of organic matter. In some polished slices of flints from Bognor, the transition from flint to agate, chalcedony, and crystallized quartz is beautifully exhibited. The curious fact, that the echinites in the chalk are almost invariably filled with flint,* while the shelly covering is converted into calcareous spar, is, perhaps, attributable to the animal matter having undergone silicification;† for the most organized parts are those which appear to have been most susceptible of silicious petrifaction. Allusion has been already made to the conversion of an oyster into flint, while the shell is, as usual, carbonate of lime. The shells of mollusca, the plated coverings of echinoderms, and the guards of the belemnites are less commonly silicified, possibly from the large proportion of calcareous earth which enters into their composition; they are more frequently changed into calc-spar, probably from water charged with carbonic-acid gas having insensibly effected the crystallization of their molecules.‡

Some specimens of silicified wood, collected from the interior of Australia, by the late Sir T. Mitchell, and now in the British Museum, are entirely permeated by silex; but on the external surface of these stems, there are some circu-

* In one instance, the shell of an echinite from the chalk is transmuted into crystallized carbonate of lime, while the lower portion of the cavity is occupied by flint, on which is a layer of crystals of calcareous spar.

† Mr. Bowerbank thinks that the cavities of the echinoderms were filled, after death, by sponge, which latter took on the silicification.

‡ See an interesting Essay on this subject, by M. Alexandre Brongniart, "*Essai sur les Orbicules Silicieux*, &c." Paris, 1831.

lar spots of chalcedony, that appear to have originated from the exudation of the liquid silex from the interior, in viscid globules distended with air, which burst, collapsed, and became solidified in their present form.

One of the most eminent naturalists and mineralogists of the United States, Mr. J. D. Dana,* has suggested that the reason why silica is so common a material in the constitution of fossil wood and shells, as well as in pseudomorphic crystals, consists in the ready solution of silex in water at a high temperature (a fact affirmed by Bergman),† under great pressure, whenever an alkali is present (as is seen at the present time in many volcanic regions), and its ready deposition again when the water cools. A mere heated aqueous solution of silica, under a high pressure, is sufficient to explain the phenomenon of the silicification of organic structure. Mr. Dana states, that a crystal of calc-spar in such a fluid being exposed to solution from the action of the heated water alone, the silica, depositing itself gradually on a reduction of temperature, takes the place of the lime, atom by atom, as soon as set free. Every silicified fossil is an example of this pseudomorphism; but there seems to be no union of the silica with the lime, for silicate of lime is of rare occurrence. (See also vol. i. p. 99, &c.)

That silicification is induced under circumstances connected with a high temperature, we have a remarkable instance in the petrified wood observed in Kerguelen Island, by Captain Sir James Ross. Seams of coal, varying in thickness from a few inches to four feet, are imbedded in trap-rock; and numerous fossil trees were found lying under a bed of shale, which was covered by a mass of basalt several hundred feet thick. Some portions of the wood were so

* Americ. Journ. Science and Arts, vol. xlviii. p. 84.

† Bergman first determined the solubility of silex in simple water, aided by heat, and demonstrated its existence in the Geysers, and other boiling springs of Iceland. *See also* Parkinson, Org. Rem. vol. i. p. 324.

little altered that it was necessary to take them in the hand to be convinced of their fossil state; and the wood was found passing from that condition into charcoal which would burn freely; while other portions were so completely silicified as to scratch glass.* In fact, the permeation of vegetable tissues by aqueous solutions of silex at a high temperature appears to be one of the necessary conditions under which silicification takes place.

33. FOSSIL PLANTS OF THE COAL.†—I proceed to the examination of the flora of the Carboniferous era. The layers of pure coal, as we have already stated, are wholly composed of carbonized vegetables; and, when we consider that these beds are from ten to thirty feet and even nearly fifty in thickness,‡ it would seem difficult to account for such an immense accumulation of wood, and plants, and foliage as would be required to produce so enormous an amount of carbon, without any intermixture of earthy detritus, had we not such illustrative examples of analogous modern carbonaceous deposits, as those brought forward by Sir C. Lyell, and previously alluded to. The shales above the coal are highly charged with carbonaceous matter, and contain a profusion of leaves and stems. The vegetable remains are always in a carbonized state; but the leaves sometimes possess such a degree of tenacity and elasticity as to be separable from the stone. The leaves and seed-vessels which occur in the iron-stone-nodules have, in many instances, undergone a metallic impregnation, as is often the case in specimens from Coalbrook Dale. Brilliant sulphide

* Voyage of Discovery in the Southern and Antarctic Regions, in 1839-43.

† Plates I. to XXX. of the Pictorial Atlas of Organic Remains (from Artis and Parkinson) are devoted to Fossil Plants.

‡ Besides the instances of thick coal-seams mentioned at p. 683, we *may add that* at Wilkesbarre in Pennsylvania an anthracite, 30 feet thick, *is worked*; and near Cracow in Poland there is a coal-bed between 40 [illegible] thick.

ı (iron-pyrites), in some examples, permeates the en- ·getable tissue; in others, the stems and leaflets are ·d by white hydrated silicate of alumina (pholerite);* many, by crystals of galena, or sulphide of lead, and of , or sulphide of zinc. In the sandstones, the stems ·enerally a carbonaceous crust, and their internal ıre is sometimes found in a calcareous, and occasionally icified, state.

Coal-plants which have been accurately determined † t to some hundreds of species, of which two-thirds her members of the family of Ferns, or belong to ex- rders of plants that united the characters of the ex- cryptogamic and gymnospermous classes.‡ The re- ·r consist of Coniferæ, some Cycadaceæ, and a few ng monocotyledonous or dicotyledonous plants.§ But

Pict. Atlas Org. Rem. pl. 5, figs. 10, 11. Geol. Jour. vol. xiii.

his "Steinkohlen-Formation Sachsen's," 1856, Dr. Geinitz has d the latest results of his long and diligent examination of great of the plant-remains of the coal; and has shown that, from the afforded by the carefully collected leaves, stems, roots, and ts, many of the hitherto accepted "species" must be merged to- different parts of the same plant having been severally regarded ents of distinct plants, or variously conditioned individuals of one ıaving been catalogued as distinct species. Would that there re British geologists able and willing to rival Gœppert and Geinitz laborious, conscientious, and successful elucidation of the frag- and often obscure relics of the Carboniferous Flora!

ıs the Lycopodiaceæ and Coniferæ meet, as far as analogical re- ces are concerned, in the *Lepidodendron;* and the Ferns and the n the *Sigillaria;* whilst the Equisetaceæ appear with added cha- n the *Annulariæ* and the *Calamites.*

lphe Brongniart's Memoirs on Fossil Vegetables—especially his ne," and "Histoire des Végétaux Fossiles," 1828, and "Tableau es de Végétaux Fossiles," 1849—should be consulted for philo- views of the condition of the terrestrial vegetation at the Car- us period. With reference to this subject he observes, in his ıg memoir on the genus *Nœggerathia* (Annales des Sc. Nat. 1846), Carboniferous Flora appears to have been limited to two of the numerous species are undescribed, and new forms are c tinually being discovered.

The British species exceed 200; * I will presently pl before you a few of the predominant forms, which will se to convey a general idea of the nature of the Carbonifer Flora; for the greater number of the plants that are fo in the British coal-mines also occur in Europe and No America,—even in the Arctic regions.

The following tabular outline of the characteristic families and gen classification of existing vegetables † will be useful to the student, w referring the fossil plants to their modern representatives.

- **Acotyledonous or Cryptogamic.**
  - Thalogens; or Cellular Cryptogams. Diatomaceæ, Des diaceæ, Confervæ, Seaweeds, Charæ, Mould, Mushroo Lichens, &c.
  - Acrogens; or Vascular Cryptogams. Liverworts, Horseta Mosses, Club-mosses, Pepperworts, Ferns, &c.
- **Phanerogamic.**
  - Monocotyledonous.
    - Endogens. Grasses, Palms, Orchi Rushes, Lilies, &c.
  - Dicotyledonous.
    - Gymnogens; or Gymnospermous Dicoty dons. Cycadaceæ and Coniferæ.
    - Exogens; or Angiospermous Dicotyledo Most of the European flowering he and trees (except the Conifers,—fi yews, &c.).

That we may have a general view of the Carboniferous Flora, following synoptical résumé of the specific determinations of the cc plants, by Gœppert and Geinitz, is given. These results are founded a close study of the plants of the Upper and Lower Coal of Saxony, co pared with those of the coal-measures of Silesia and other parts of Continent, and of Britain; and necessarily afford valuable statistics of vegetation of the Coal-period, although other palæontologists may

grand divisions of the vegetable kingdom, namely, "les Cryptogan acrogènes ou vasculaires, et les Phanérogames dicotyledones gym spermes." See also Lyell's "Manual of Geology," 5th edit. p. 373.

* See Morris's "Catalogue of British Fossils," 1854; and Phillip "Manual of Geology," p. 226.

† See "Manual of Natural History" (Van Voorst), for a detail classification. For structure, see Carpenter's *Microscope*, chapters 6, and 8.

inclined to disagree in many points with the results at which these eminent German geologists have arrived.

A. Acotyledones.

1. FUNGI.
   Depazites, Excipulites, Gyromyces (one species of each).
2. EQUISETACEÆ.
   Equisetites (2 species), Calamites (6 spec.).
3. ASTEROPHYLLITÆ.
   Asterophyllites (6 spec.), Annularia (3 spec.), Sphenophyllum (6 spec.).
4. FILICES.
   a. *Sphenopterideæ.*
      Sphenopteris (18 spec.).
      Hymenophyllites (7).
      Schizopteris (4).
   b. *Neuropterideæ.*
      Odontopteris (3 spec.).
      Neuropteris (5).
      Cyclopteris (3).
      Dictyopteris (2).
   c. *Pecopterideæ.*
      Cyatheites (10).
      Alethopteris (10).
      Oligocarpia (1).
   d. *Protopterideæ.*
      Caulopteris (3).
      Palæopteris (1).
      Psaronius (1).
      Megaphytum (1).
5. LYCOPODIACEÆ.
   Lycopodites (5).
   Selaginites (1).
   Lepidodendron (2).
   Sagenaria (5).
   Lepidophyllum (1).
   Aspidaria (4).
   Halonia (3).
   Knorria (3).
   Cardiocarpon (4).

B. Dicotyledones.

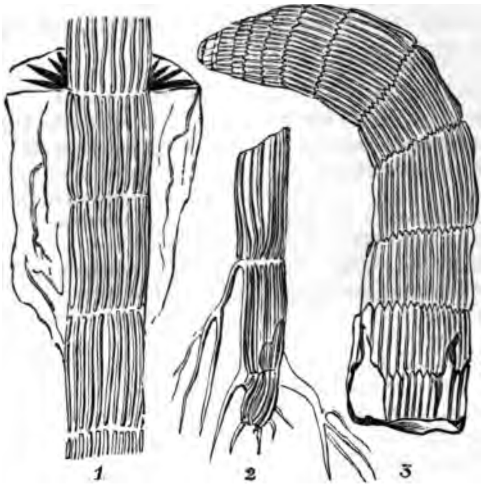
6. NŒGGERATHIEÆ.
   Cordaites (2).
   Nœggerathia (4).
   Rhabdocarpos (4).
7. CYCADEÆ.
   Trigonocarpon* (3).
8. (?)
   Carpolithes (3).
9. CONIFERÆ.
   Pinites.
10. SIGILLARIÆ.†
   Sigillaria (13).
11. STIGMARIÆ.
   Stigmaria.‡

* Dr. Hooker refers the fruits thus named to *Coniferæ.*

† Closely related to the *Lepidodendron,* according to Dr. Hooker.

‡ Gœppert and Geinitz regard the *Stigmaria ficoides* as an independent plant; and consider others of the so-called Stigmariæ to be the roots of *Sagenariæ.*

34. EQUISETACEOUS PLANTS. — The stems of several gigantic plants (*Calamites*) allied to the *Equisetum fluviatile*, or Horse-tail of our marsh-lands, are very abundant in the coal-measures. While the recent species seldom exceed two feet in height, and half an inch or an inch in diameter, the fossil stems often attain twenty or thirty feet in height, and



LIGN. 163.—CALAMITES FROM THE COAL-FORMATION.

Fig. 1. Portion of a stem, with half of a whorl of leaves or bracts. (Half nat. size.)
— 2. Portion of stem with roots. (Half nat. size.)
— 3. Terminal portion of a stem [drawn upside down]. (One-fifth nat. size.)

fourteen inches in diameter. The *Equisetites columnaris* is a common species of this kind of plant in the Lower Oolite of Yorkshire; and both the Calamite and the Equisetite are occasionally found in an erect position in the strata.*

* See Dawson's remarks on Upright Calamites at Pictou, Journ. Geol. Soc. vol. vii. p. 194, and vol. x. pp. 21 and 35; also T. T. Wilkinson's notice of Upright Calamites, accompanying a considerable number of fossil upright and rooted trees at Burnley; Lanc. and Chesh. Hist. Soc. ix. p. 101.

Calamites. The plants of this extinct genus much resemble the Horsetail, being furrowed longitudinally, and intercepted with joints or nodes. But in several points they differ, both in external characters and in internal structure.* Calamites are so abundant in the coal as to prove that they constituted an important feature in the flora of the countries of the carboniferous age; and they have also been found in strata both above and below the coal, and range from the Devonian to the Permian, and probably to the Jurassic period. A small fragment of the terminal portion of a stem, with rootlets, is represented in *Lign.* 164, and illustrates the characteristic tubercles accompanying each articulation, and marking probably the place of attachment of bracts in the upper, and rootlets in the lower part of the stem.

LIGN. 164.—CALAMITES CANNÆFORMIS; from Coalbrook Dale.

The stem of the *Calamodendron* (Brongniart) consisted of, 1st, an outer thin cylinder of bark and wood, of a high organization, externally marked with longitudinal furrows and riblets; and 2ndly, an inner pith or cylindrical axis of soft tissue, also ribbed lengthwise, but distinctly marked by transverse joint-like depressions, forming such articulations as those of the common Calamite. Along these cross-lines the interrupted riblets of the pith met and dovetailed one with another; and from the upper end of each riblet, as

* See J. S. Dawes on the Calamite, Geol. Soc. Journ. vol. vii. p. 196; where many references to other writers on these peculiar fossil plants will be met with. See also Brongniart's and Williamson's Elucidation of the Structure of Calamites and Calamodendron, in Lyell's "Manual," 5th edit. p. 368.

in Calamites, a bundle of vessels went off into the out wood.

LIGN. 165.—ASTEROPHYLLITES EQUISETIFORMIS; from Coalbrook Dale.

*Asterophyllites.** Plan with verticillate leav are common in the co shales; they have be named *Asterophyllit Annularia,*† *Sphenophy lum,*‡ &c. Several these slender whorl-le ed plant-remains a equisetaceous in the aspect; and some we the branches and folia of the Calamodendro Others were probabl small plants aboundin in the shades of th swampy forests; an others long floating wa ter-plants. Two of the usual forms are here represente (*Ligns.* 165 and 167, *fig.* 1).

35. FOSSIL FERNS.—The *Brake* or Fern of our common and waste lands is a familiar example of a remarkable an numerous family of plants, distinguished by the peculia distribution of their seed-vessels. The arborescent fern of the tropics rise into trees from thirty to forty feet i height, their stems being marked with scars from the deca of the leaf-stalks, and their summits covered with an elegan canopy of foliage; § their general appearance is shown i

* *Star-leaf.* Medals of Creation, p. 146. † Petrif. p. 27, *Lign.* 2

‡ *Wedge-leaf.* Medals, p. 148, *Lign.* 43.

§ A lucid and pleasing description of the external features of a tre fern may be found among the many graphic pictures of plants and a mals, of which Mr. Gosse's suggestive work, entitled "Omphalos," mainly composed (pp. 129--132).

Lign. 180, *fig.* 5, p. 754. The leaves of the herbaceous species are very elegant, and present great variety in their forms, and in the mode in which the veins of the leaf are

1 2

LIGN. 166.—FROM THE CARBONIFEROUS STRATA AT BURDIE-HOUSE, SCOTLAND.

Fig. 1. Sphenopteris linearis. Fig. 2. Sphenopteris affinis.

disposed; from the character of the latter, M. Adolphe Brongniart has established the generic distinctions of the fossil plants of this family. The beautiful state in which these remains occur in the coal-shale is shown in the specimens before us (*Ligns.* 166, 167, *fig.* 2, and 169, *fig.* 3). The young and still uncoiled (or circinate) leaves, and the fructification on the back of the adult leaves, are sometimes preserved.

The stems of ferns, with their elliptical cicatrices, or leaf-scars, bear some resemblance to those of the palms, but are readily distinguished on account of the longest diameter of the scars being vertical, while in the palms it is transverse: sections of the stems of these two tribes have also distinctive characters.* Fossil fern-stems are known as *Caulopteris* and *Psaronites* †

* *Végét. Fossiles, tom. i. pl. 37.* † Stenzel; Ueber Farn-wurzeln, 1857

The large tree-ferns are confined almost exclusively to the

LIGN. 167.—FROM COALBROOK DALE.
Fig. 1. Asterophyllites. Fig. 2. Pecopteris.

tropics; humidity and heat being the conditions most favourable to their development. In the carboniferous rocks there are about 100 species of ferns, nearly all of which belong to the tribe of *Polypodiaceæ;* the common *Polypody,* so frequent on old walls, will convey an idea of the characters of their foliage. The fossil species present great variety and elegance in the form and disposition of the fronds and pinnules. The *Pecopteris* (*Lign.* 167, *fig.* 2, and 168, a genus containing upwards of forty British species, is of frequent occurrence in the coal-shales, and abounds also in the Lower Oolite of Yorkshire.*

LIGN. 168.—PECOPTERIS ADANTCIDES; from Coalbrook Dale.

* See Medals of Creation, pp. 109—124, for figures and descriptions ...ns. Also Bronn's *Lethæa* Geogn., &c.

36. SIGILLARIA.—Among the most common and striking jects that arrest the attention of a person who visits a coal-ine for the first time, and examines the fossil remains pro-sely scattered around him, are long flat narrow slabs of a aly substance, having the surface fluted longitudinally, and iformly ornamented with rows of deeply imprinted sym-trical figures, disposed with great regularity (*Lign.* 169). ese relics are the flattened stems, with or without the rk or rind, of trees of large size: the imprinted markings the surface being the scars left by the separation of the

LIGN. 169.—SIGILLARIÆ AND FERN, FROM THE COAL-MEASURES.

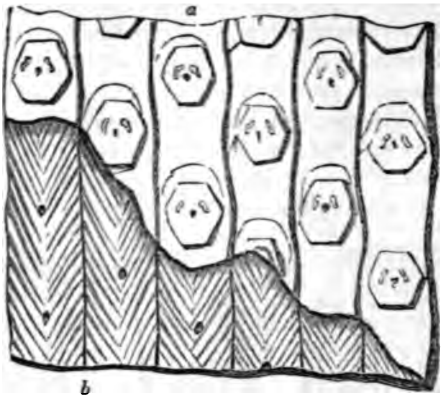
(One-fourth the natural size.)

Fig. 1. Sigillaria Voltzii, from the anthracite of Baden; *a*, the external surface; *b*, the inner surface, a portion of the outer bark being removed.
— 2. Sigillaria Sillimani: from the coal-mines of Pennsylvania.
— 3. Pecopteris Miltoni; a specimen showing the young frond coiled up like a crosier.

tioles or leaf-stalks.* The name *Sigillaria* has been ven to these extinct trees, from the impressions appearing if made by a seal or die. These stems are generally und broken to pieces, and, when lying in a horizontal posi-

* The markings left on a cabbage-stalk by the removal of the leaves of a similar nature. Figures of Sigillariæ are given in Plates XIX. and . of the Pictor. Atlas *Org. Rem.*

tion in the strata, are quite flat from the pressure of the superincumbent deposits.



LIGN. 170.—SIGILLARIA SAULII, A PORTION OF A FLATTENED STEM, FROM THE COAL-MEASURES.

a. External surface marked by the scars of the petioles.
b. The inner surface exposed by the removal of the bark.

The stems vary from a few inches to three feet in circumference, and specimens have been discovered that indicate a length of sixty feet. They often escape compression, and stand perpendicularly, intersecting the horizontal strata, and having roots proceeding from the base. They are generally surrounded by an envelope, an inch in thickness, of fine, crystalline, bituminous coal. The longitudinal plaitings, which are the characteristic marks of the Sigillariæ, are commonly indistinct at the base. A specimen figured in the beautiful and highly interesting work of Lindley and Hutton * was ten feet high, and two feet in diameter at the base (*Lign.* 171). Its roots were in shale, immediately above the main bed of coal, and the trunk extended ... 'eral strata of shale and sandstone.

* "The Fossil Flora of Great Britain."

The *Sigillaria* was a tall tree, with a bare trunk, regularly pitted by the leaf-scars. It branched at the summit, and appears to have borne long narrow leaves. Its fruit is not known. In its internal structure, which has been examined by Brongniart, King, Hooker, Bowman, Dawson, and others, the *Sigillaria* shows much analogy to that of the *Cycadeæ*, but exhibits also the scalariform tissue of the *Acrogens*; and is regarded as of higher organization than the Lepidodendron, and belonging to a peculiar family of the great division of Gymnospermous Dicotyledons.* It was a plant consisting of soft areolar tissue, with a hard woody central cylindrical axis, and a hard bark. There are many species known of this extinct genus. The *Sigillariæ* abounded in the swampy jungles of the Coal-period, and have evidently supplied the chief mass of the now carbonized material of most coal-seams, whilst their roots (*Stigmariæ*) still permeate the *underclays* in every direction.

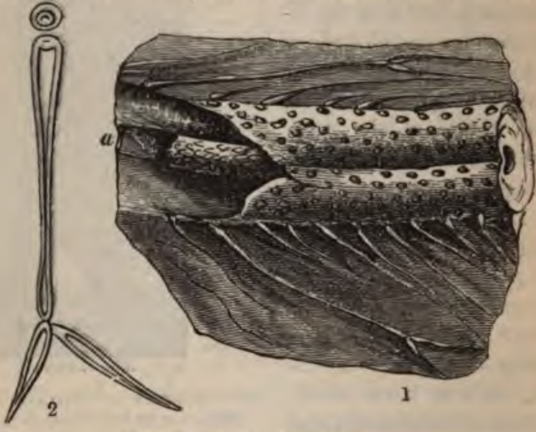
LIGN. 171.—STEM OF SIGILLARIA PACHYDERMA; in the Jarrow Coal. *Ten feet high.*

37. STIGMARIA.†—The fossil vegetables known under this name, which are so abundant in the underclay of the

* See Dr. Hooker's Remarks on *Sigillaria*, Mem. Geol. Survey, vol. ii. part 2, p. 421; and King on *Sigillaria*, Edinb. N. Phil. Journ., 1844.

† Dr. Hooker's *Memoir on Stigmaria*, Mem. Geol. Surv. vol. ii. part 2, p. 431; *King, loc. cit.;* Medals, p. 132, &c.

coal-beds,* long excited the curiosity of collectors, and set at defiance all attempts to determine their botanical characters, until recent discoveries proved the correctness of M. Adolphe Brongniart's conjecture, that they were the roots of *Sigillariæ*. These bodies are of a sub-cylindrical form, reaching sometimes several feet in length, and are often ten or twelve inches in circumference. The surface is covered with oval or circular depressions with a small tubercle in the



LIGN. 172.—STIGMARIA FICOIDES.

Fig. 1. Portion of a root (1/3 nat. size). The internal axis is seen at *a*.
— 2. One of the rootlets, with a corresponding tubercle, to show the mode of articulation.

middle, disposed in quincunx order. When broken across, a small cylindrical axis or core is found to extend longitudinally throughout the stem (*Lign.* 172). When observed in the underclay, long tapering fibres or rootlets are found attached to the tubercles of the pits with which the surface is covered; and these are sometimes several feet in length.

* Prof. Gœppert has remarked that *Stigmaria ficoides* may be regarded as one of the most prevalent of the coal-plants. "Ein-und-dreissig. Jahresbericht. Schles. Ges." p. 81.

The internal structure of the *Stigmariæ* presents a ligneous axis, or cylindrical woody bundle of vessels, originally traversing the centre of the pithy root, but in the fossils generally lying nearer to one side than the other of the more or less compressed root, owing to its having sunk in the softened tissue during the rotting of the pith, and before the root was fossilized. This woody axis resembles the woody zone found in sections of the *Sigillariæ*, except that the ring of medullary tissue possessed by the latter is wanting; a difference, as Ad. Brongniart remarks, precisely similar to that existing between the roots and the stems or branches of a dicotyledonous tree, in which the woody cylinder is associated internally with bundles of medullary tissue, that are absent in the roots

LIGN. 173.—STEM AND ROOTS OF A SIGILLARIA; in a Coal-mine near Liverpool
a, The trunk traversing a bed of coal.
b, The roots (*Stigmariæ*) spreading out in the underclay.

of the same tree. This opinion, long since advanced by the eminent French savant, has been confirmed by Mr. Binney's discovery, *in the coal-strata* at St. Helen's near Liverpool, *f an upright stem of a* *Sigillaria*, nine feet high, with ten

(*From the Geol. Soc. Journ.* vol. v. p. 359.)

LIGN. 174.—STOOL OF A SIGILLARIA BROKEN OFF CLOSE TO THE ROOTS.

Having shown, by evidence obtained in the Cape Breton coal-field, that the Sigillaria was provided with roots peculiarly adapted for flourishing on a soft muddy soil, Mr. Brown refers to the fossil roots figured above, as perfectly resembling the "dome-shaped fossil" of Lindley and Hutton, but as being really the stool of a Sigillaria, the stem of which has been broken off near the root, and the hollow woody cylinder of which had, after the decay of the loose cellular tissue within, been bent down and doubled over by the pressure of the accumulating mud outside, so that the aperture was effectually closed, leaving only a few irregular cicatrices, of three or four inches in length, converging at the apex.—*Loc. cit.* p. 360. See also Mr. Dawson's remarks, to a like effect, *ibid.* vol. x. p. 31.

oots, several feet long, attached, and extending in the underlay in their natural position (as shown in *Lign.* 173); these oots being undoubted *Stigmariæ*.*

In the floor of the Victoria Mine, at Dunkinfield near Manchester, at the depth of 1100 feet from the surface, Mr. Binney discovered a magnificent specimen of Sigillaria, which xhibited on its stem the respective characters of three supposed species (*S. pachyderma*, *reniformis*, and *organum*), and ad stigmaria-roots, which were traced twenty feet.†

In the Sidney coal-field, at Cape Breton, several upright tems of Sigillariæ, having roots that are undoubted Stigmariæ, have been discovered; and in the Pictou coal, in Nova Scotia, the same fact has been noticed, and communiated to the Geological Society of London. (See also p. 689.)

The Rev. Henry Steinhauer was among the first to regard the Stigmariæ as *roots* of trees, in an interesting and well-illustrated memoir, entitled "Fossil Reliquia of Unknown Vegetables in the Coal-strata" (Transact. Americ. Phil. Soc. New Series, vol. i. p. 273, 1818). Lindley and Hutton quoted Steinhauer's observations, and described the Stigmariæ as radiating, massive, floating aquatic plants.‡

Prof. Gœppert has evidence to show that some of the Stigmariæ were great, branching, and even anastomosing roots, or rhizodes, of water-plants; and resembled the spread-

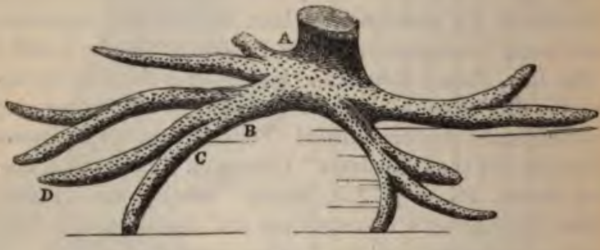
* Phil. Mag. 3rd ser. vol. xxvii. p. 241. Report Brit. Assoc. 1843. Several interesting communications on the coal-plants and the coal-measures may be found in these valuable Reports; for instance, Mr. Buddle's Report on the Newcastle Coal-measures, in the volume for 1838; Mr. Milne on the Berwick and North Durham Coal-field, 1838; Mr. Binney on the Lancashire Coal-fields, 1842, and by Messrs. Heywood and Williamson, 1837; Lord Greenock and Mr. Craig on the Scotch Coal-fields, 1834 and 1840; &c.

† Geol. Soc. Journ. vol. ii. p. 390. Over the door of the room containing the fossil vegetables in the British Museum, there is a Stigmaria twenty-six feet long, with numerous rootlets.

‡ See "Fossil Flora of Great Britain;" and Buckland's "Bridgewater Treatise."

ing roots of the great water-lilies. Thus far Lindley's hypothetical reference of the Stigmariæ to aquatic plants is partially supported; but Brongniart, Binney, Bowman, King, Brown, Dawson, and others have brought forward good evidence of the majority of the Stigmarian bodies being really the stools and roots of trees.

As there is considerable variety in the form and disposition of the tubercles of the Stigmariæ, it is probable that some of them may be the roots of other trees of the carboniferous deposits, with the stems of which they are associated.*



(*From the Geol. Soc. Journ.* vol. iv. p. 47.)

LIGN. 175.—BASE OF THE STEM OF A TREE WITH STIGMARIAN ROOTS; from Cape Breton. At A, B, C, D, there were portions of a coaly bark.

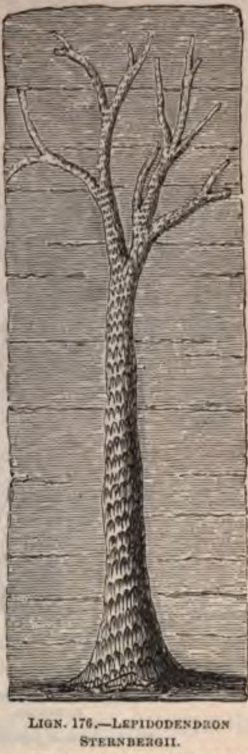
Mr. Richard Brown has described † a rooted stem (*Lign.* 175), found by him in the Coal-measures of Cape Breton, as that of a *Lepidodendron.* Sir C. Lyell, however, refers it to *Sigillaria.*‡ We must recollect, in this instance, that there are some species which it is difficult to define generically either as Sigillaria, Sagenaria, or Lepidodendron, so similar sometimes are the features presented by the stems, or rather parts of the stems.

* *Such* as *Sagenaria*, &c. See Gœppert's and Geinitz's Memoirs.

† *Quart.* Journ. Geol. Soc. vol. iv. p. 47.

‡ *Manual*, 5th edit. p. 370.

38. LEPIDODENDRON.*—This belongs to a tribe of plants which has largely contributed to the formation of the coal-strata, and whose remains rival in number and magnitude the Calamites and Sigillariæ. The name, which signifies *Scaly-tree*, is derived from the imbricated appearance of the surface of the stem, occasioned by the form and arrangement of the little angular imprints or scars left by the removal of the leaf-stalks (*Ligns.* 176, 177). Some of these trees have been found almost entire, from their roots to the topmost branches; as in the example here figured (*Lign.* 176), which was nearly forty feet in length. The foliage consists of simple linear leaves, which are spirally arranged around the stem, and appear to have been shed from the base of the tree with age. The markings produced by the attachment of the leaves are never obliterated. In their external configuration, mode of ramification, and disposition of the leaves, and in some points of their internal structure, these trees accord closely with the *Lycopodiaceæ*, or Club-mosses. These are small herbaceous plants, inhabiting woods and bogs; their leaves are simple and imbricated, that is, lie over each other like scales. Most of them trail on the ground, but a few



LIGN. 176.—LEPIDODENDRON STERNBERGII.

A fossil tree, thirteen and a half feet wide at the base, and thirty-nine feet long.

Such a specimen, but without its outer bark, was discovered in the Bensham coal-seam, in the Jarow coal-field: see the "Fossil Flora," Pl. 203.

* Hooker, *Mem. Geol. Surv.* vol. ii.; Medals, p. 136.

species are erect; * the tropical forms, which are the large[st] do not exceed three feet in height. But notwithstanding th[e]

1 2

LIGN. 177.—Fig. 1.—TERMINAL PORTION OF A BRANCH OF LEPIDODENDRON. Coal-sh[ale] Newcastle.

Fig. 2.—Scars of petioles (nat. size).

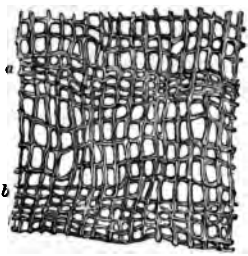
disparity in size, M. Brongniart has shown that the Lepi[do]dendra must be regarded as gigantic plants closely allied [to] this family. They may be regarded, in fact, as arboresc[ent] Lycopodiaceæ, comparable in size to the largest pines; [and] they formed extensive forests during the carbonifer[ous]

* *Such as Lycopodium densum*; Hooker, Mem. Geol. Surv. vol. ii. 2, p. 423

period, beneath whose shade flourished the lesser ferns and associated plants.

The fruit of the living Club-mosses is an oval or cylindrical cone, which in some species forms an imbricated spike at the extremity of the branches; and there are numerous fossil fruits of this kind found together with the stems and leaves of the Lepidodendra, and in some instances attached to the branches; they have received the name of *Lepidostrobi*, or scaly-cones.*

Besides being preëminently a coal-plant, the *Lepidodendron* is found in the Devonian strata of the United States, of Caithness, and Thuringia; and in the Mountain-limestone of Northumberland.† It occurs also in strata of Carboniferous or Devonian age, both in Australia and South Africa.



LIGN. 178.—Transverse section of a portion of the stem of a recent Pine (*Pinus strobus*), highly magnified.
a, b, Portions of concentric annual layers.

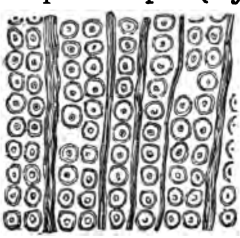
Long narrow branches, covered with numerous small leaves or bracts, occur in the coal-measures, which are regarded as being fossil forms of club-mosses, and are termed *Lycopodites*. Similar plant-remains have been found in the Tertiary and Oolitic strata, and some of these have been correctly referred to the Coniferæ. Indeed, the *Dacrydium cupressinum* of New Zealand, with its long pendant lycopodial branches and regularly scarred stem, and other similar conifers, should remind us that the

* Pict. Atlas, pl. ix. f. 1, and pl. xxxiii.; and Medals of Creation, *Lign.* 40. The structure aud affinities of the Lepidostrobi are well worked out and illustrated by Dr. Hooker, in the Mem. Geol. Surv. vol. ii., where Lepidodendron, Sigillariæ, and Calamites, &c., are also made the subjects of elucidation.

† *Tate, Fossil Flora of the* Mountain Limestone, p. 297.

external form of one family of plants is imitated by another. It is from the fructification that the most decided characters of plants can alone be drawn.

39. CARBONIFEROUS TREES AND PLANTS.*—It was formerly supposed that no vestiges of coniferous plants and trees, which occur so abundantly in the secondary formations, were present in the coal; but Mr. Witham, by microscopical examination, ascertained that trees of this type constituted no inconsiderable portion of the flora of the carboniferous epoch; and remains of this order have since been detected in the Devonian and every formation of later origin. The recent coniferæ are arborescent, dividing into numerous branches, which are disposed in most genera with considerable regularity. The transverse sections of the wood exhibit concentric annual lines of growth (as in *Lign.* 178), and the vertical show the sides of the woody fibres studded with little pores or spots (*Lign.* 179).



LIGN. 179.—Longitudinal section of pine-wood, parallel to a medullary ray; showing the rows of spots or pores.

Some of the fossil trees resemble the European pines in their internal structure: but the greater number belong to the Araucarian type, which is characterized by the rows of spots being disposed, when double, not side by side, as in *Lign.* 179, but alternately, as we have previously explained (p. 713).†

The coniferous trees ‡ of the coal have but few and slight appearances of the lines by which the annual layers are separated, and resemble in this respect the existing species of tropical regions.

* Medals, p. 164, &c.

† In the Royal Gardens at Kew, there are several flourishing trees of the *A. excelsa*, and other kinds of Araucariæ.

‡ Witham, *op. cit.*; and Quekett, Catalog. Foss. Veget. Hunterian Museum, pp. 27 and 28.

we may therefore infer that the seasons of the countries where the coal-plants flourished were subject to but little diversity, and that the changes of temperature were not abrupt.

In a quarry at Craigleith, near Edinburgh, at a depth of 140 feet, part of the trunk of a very large coniferous tree was discovered: its length was thirty-six feet, and the circumference of the base nine feet. Polished sections of this stem beautifully display the coniferous structure. A tree fifty-nine feet long, traversing twelve beds of sandstone, has since been exposed; and, as is commonly the case, the bark was carbonized, and the woody stem was in some parts in the state of sandstone, and in others silicified.

Numerous seed-vessels have been found in the coal-measures, and are known as *Cardiocarpon*, *Rhabdocarpos*, *Carpolites*, and *Trigonocarpon*. The relations of these fruits are mostly very obscure.* The *Trigonocarpa* have been referred by some to palms, and by others to Cycads; but Dr. Hooker has shown † that, although certainly having characters of structure as closely related to the Cycads as to the Conifers, yet it is to the latter that the weight of the evidence tends to refer them; and he especially points to the peculiar coniferous genus *Salisburia* (a native of China), as presenting a fructification similar to that found in *Trigonocarpon*. Dr. Hooker mentions also that, as Dr. Lindley has pointed out, the foliage of Salisburia also affords a modern analogy, for the fossil leaves called Nœggerathia, which, with some Trigonocarpon-like bodies, M. Brongniart has referred to the Cycadaceæ.

Dr. Hooker has described a fragment of cycadeous wood from the Durham coal-field; ‡ and in 1844, M. Gœppert had recognised in the carboniferous rocks of Europe four species of fossil plants which he considered referable to the Cycadaceæ.§

No well-authenticated remains of palms occur in the coal-strata.

* Fiedler; Foss. Frücht. &c. 1857. † Proc. Roy. Soc. vol. vii. p. 28.

‡ Mem. Geol. Survey, vol. ii. part 2, p. 421.

§ Annals Nat. Hist. vol. xv. p. 442. For figures and descriptions of recent and fossil cycadeous plants, see Buckland's Bridg. Treat. p. 494, and Medals, *p. 150*

40. FLORA OF THE COAL. A more extended notice of the fossil plants of the carboniferous system is not within the scope of these Lectures, and we will now take a brief review of the principal facts that have been submitted to our notice. We have seen that the most remarkable character of the flora of that remote epoch, is the immense numerical ascendance of certain peculiar tribes of cryptogamic plants, which amount to at least two-thirds of the whole of the species

1 2 3 4

LIGN. 180.—RECENT AND EXTINCT TREES.

Fig. 1. Araucaria (Gymnogen). 2. Pandanus (Endogen). 3. Arborescent Fern (Acrogen). 4. Lepidodendron (fossil).

hitherto determined. With these are associated some coniferæ, a few cycadaceæ, and some rare phanerogamic plants. The vast preponderance and magnitude of the vegetables bearing an analogy to the tribes both of acrogens and of gymnogens, but differing from existing species and genera, constitute, therefore, the most important botanical feature. Thus we have plants related to the horsetail (*Calamites*), eighteen inches in circumference, and from thirty to forty feet high; arborescent club-mosses (*Lepidodendra*) attaining an altitude of sixty or seventy feet; other great lycopodiaceous trees (*Sigillariæ*) fifty feet in height; besides tree-ferns, and a multitude of minor acotyledonous plants, with comparatively few coniferous trees. The contrast which such a flora presents to that afforded by the woods and forests of dicotyledonous trees, and the verdant turf, which now grow on the surface of the carboniferous districts of England, is as striking as the discrepancy between the zoology of the palæozoic formations and that of the present day. In *Lign.* 180, figs. 1, 3, and 4 represent some of the chief tree-like forms which flourished in the carboniferous era, namely, the coniferous *Araucaria* or Norfolk Island Pine (which is at the present day the best representative we have of some of the woody trees of the Carboniferous and Permian periods), the cryptogamic Tree-fern, and the lycopodiaceous *Lepidodendron* (no longer represented by living species). The Screw-palm or *Pandanus*, introduced in the sketch (*Lign.* 180, fig. 2) as an example of our endogenous tree, appears to have its earliest progenitors in the Jurassic period.

To arrive at any satisfactory conclusions as to the nature of the countries which supported the plants of the coal, we must consider, 1st, the geographical distribution of the related existing genera of plants, and the circumstances which conduce to their full development; and 2ndly, the probable hydrographical conditions of the earth's surface at the coal-period. It is well known that a hot climate, humid atmosphere, and the unvarying temperature of the sea are the circumstances which exert the most favourable influence on the growth of Ferns and other cryptogamic plants; low islands in tropical latitudes being the localities where these forms of vegetation flourish most luxuriantly. From the relative proportion of land and water then probably existing in this region, we may infer that the countries in which the "carboniferous" flora grew were groups of extensive islands enjoying a subtropical climate.* In the paucity of the gramineæ or grasses, which form so large a proportion of the existing floras, and the predominance of ferns, the vegetation of the coal-measures approached in some respects that of New Zealand, in which the cellulosæ form one-third of the whole, while the grasses are very few in number.†

From the researches of Elie de Beaumont ‡ and Godwin-Austen,§ who have constructed approximative charts of the carboniferous area of Western Europe, we know that the coal-measures and the mountain-limestone were deposited for the most part amongst an extensive archipelago, of which some districts of Scandinavia, Scotland, Ireland, Wales, Cornwall, France, and Northern Italy formed parts.|| Considerable, but isolated, areas of coal-deposits were formed in lakes on the table-land of what is now Central France; and, according to Mr. Godwin-Austen, equally extensive lake-systems gave origin to the old-red sandstones and conglomerates ¶ of Scotland and Ireland, and probably of that of South Wales also

41. ATMOSPHERIC CONDITIONS DURING THE CARBONIFEROUS EPOCH. — It appears remarkable that amidst the luxuriant vegetation which prevailed on the dry lands during

* See chap. vii. of Lyell's "Principles of Geology," for the full consideration of probable climatal conditions with given proportions of land and sea.

† See Medals of Creation, vol. i. p. 210; and Lyell's "Principles," p. 87.

‡ See Beudant's *Géologie*.

§ See Quart. Journ. Geol. Soc. vol. xii. pl. i

|| A very important feature of this old archipelago was a narrow tract of land, or of shoals, reaching from the Franco-Belgian frontier to Somersetshire and the south of Ireland; now recognised chiefly in the Ardennes, on the east, and the Mendips on the west, and by the presence of the elevated and denuded valley of the Weald, and by other geological features along its line. As the coal-measures and the coal-bearing mountain-limestone lie against the flanks of this old transverse ridge, and as it is not covered up by the whole series of the secondary strata, but only by the cretaceous and tertiary series, it is considered probable that coal-beds might be found at much less than 2000 feet below the surface in the neighbourhood of London; especially as coal has already been met with in a deep boring at Calais, on the same line of old rocks. At Harwich, a deep boring has reached this subterranean ridge at about 1000 feet in depth; but it is there composed apparently of rocks *older than* those of the coal-series.

¶ Quart. Journ. Geol. Soc. vol. xii. p. 51, &c.

the Carboniferous epoch, there should not have existed contemporaneous herbivorous quadrupeds; but not a relic of any animal of this kind has been discovered in the coal-strata. Indeed, with the exception of the Iguanodon of the Wealden (*see* p. 436), no remains of large vegetable feeders * have been found in any of the deposits anterior to the eocene, in which first appear relics of the herbivorous pachyderms. The coal-measures of Nova Scotia alone present vestiges of phytophagous terrestrial mollusca.

It was an opinion once very generally entertained, and the idea still seems to find favour, that previously to and during the Carboniferous period the atmosphere was so charged with carbonic-acid gas as to be unfitted for the respiration of animals of a higher order than reptiles; and that the dense and luxuriant vegetation of that epoch was designed to purify the air, by elaborating coal, and thus abstracting the superabundance of irrespirable gas, and setting free a corresponding proportion of oxygen: thus rendering the surface of the earth suitable for the existence of terrestrial reptiles, and ultimately of birds and mammalia. But Sir C. Lyell has argued that, so far as we know, if any change were induced in the constitution of the atmosphere by such an agency, it would be the reverse of that assumed; for an excess of vegetation would tend to diminish the average amount of carbonic acid, and consequently the air must have been purer than in the succeeding epochs.† It is therefore probable that the absence of herbivorous animals cannot be explained by unfavourable atmospheric conditions: and again we may point to New Zealand as a country having a luxuriant vegetation, yet without herbivorous quadrupeds.‡

42. Formation of Coal-measures.—From the facts which have passed under our examination,§ we may now advantageously consider what were the circumstances which gave rise to these prodigious layers of carbonized matter

* The *Plagiaulax* of Purbeck and the *Stereognathus* of Stonesfield were smaller herbivores. The other known mammals of the secondary period were probably insectivorous.

† Lyell's "Travels in North America," vol. i. p. 152; and "Principles," p. 248.

‡ The only indigenous mammals in New Zealand are one species of *Rat* and another of *Bat;* and there are no large reptiles whatever.

§ See *especially p. 681, &c.*

unmixed with other materials,—these immense beds of vegetables, from which animal remains are often almost wholly excluded;—and whether accumulations of trees and plants, which in after-ages shall present phenomena of a like nature, are in progress at the present time?

The manner in which the carboniferous strata have been deposited has been a fruitful source of discussion among geologists. Some have contended that the coal-measures were originally peat-bogs, and that the successive layers were occasioned by repeated subsidences of the land; —others, that the vegetable matter originated from rafts, or masses of drifted forest-trees, like those of the Mississippi,* which floated out to sea, and there became ingulfed;—others suppose that they were formed in inland seas or lakes, the materials of the successive beds being brought down by periodical land-floods: and the supporters of each hypothesis adduce numerous facts in corroboration of their respective opinions. There can be no doubt that coal may be, and has been, formed under each of these conditions; and that at different periods, and in different localities, all these causes have been in operation; in some instances singly, and in others in combination. An interesting example of the latter conditions is described by Prof. Dawson, in the *Canadian Naturalist* (October, 1857), as occurring at Pictou, where some portions of the coal-measures present appearances suggestive of "the idea of patches of grey sand rising from a bottom of red mud, with clumps of growing Calamites, which arrested quantities of drift-plants, consisting principally of Sternbergia and fragments of much-decayed wood and bark, now in the state of coaly matter too much penetrated by iron-pyrites to show its structure distinctly. We thus probably have the fresh-growing Calamites, entombed along with the debris of the old decaying Conifers of some neighbouring shore; furnishing an illustration of the truth, that the most ephemeral and perishable forms may be fossilized and preserved contemporaneously with the decay of the most durable tissue. The Rush of a single summer may be preserved with its minutest striæ unharmed, when the giant Pine of centuries has crumbled into mould. It is so now, and it was so equally in the Carboniferous period."

That some of the isolated basins of coal may be carbonized peat-bogs is not improbable, considering that peat often occurs in beds including trees in an erect position, and extending over extensive tracts of country;

* On this river and its branches accumulations of timber, forming rafts 10 miles long, are said to have occurred.—Lyell's "Principles," p. 267.

nodern peat-bogs (see p. 66) layers are occasionally found having choidal fracture and lustrous appearance of coal.

r coal-measures may have been accumulated in fresh-water lakes, ries, or in lagoons of fresh or of brackish water, into which the sea casional irruptions. To this class would belong the greater pro- of the known coal-measures.

carboniferous strata, intercalated with sandstones and limestones ng marine remains in abundance, like those of Russia (see p. ust have been deposited in the sea.

occasional erect position of the stems and the preservation of leaves do not invalidate this inference; for in the rafts formed ntangled floating forests of the American rivers, trunks of trees ly occur upright; and in the interior of these rafts grasses and lants are often found entire. Such masses, therefore, might be nany hundred miles, and yet the imbedded fragile species, pro- y the external network of entangled branches, remain uninjured; lergoing bituminization, while enveloped by the soft mud per- the mass, might become changed into durable forms, like those ound in the natural herbaria of the coal-measures.

erticality of tree-trunks in some of the strata of the carboniferous as, for instance, in the Sandstone of Cragleith, near Edinburgh— e originated simply from the trees having floated, and been ulti- noored, with their stems upright, or nearly so, in consequence of ts being loaded with soil. This is a constant occurrence in the ods of the American rivers; the *snags*, as they are termed, which nder the navigation up the stream difficult and perilous, being oy drifted trees fixed by their stumps in the river-bottom, and to an oblique direction by the current.

in an upright position are often carried out to sea, and have been from land, floating with their topmost branches above the water. ese circumstances they have been instrumental (like sea-weeds ergs, in different degrees) in carrying pebbles and blocks of m the land into the deep abysses of the ocean, or to far distant

COAL-MEASURES ORIGINATING IN SUBMERGED LANDS.

theory, so ably advocated by Sir C. Lyell and other t geologists, of the formation of coal-measures from d submergences and elevations of lands covered with orests (see p. 682, 684), seems to be especially appli- o those *carboniferous* formations which are made up of regular alternations of coal with beds composed of such earthy materials as render it probable they were once capable of supporting a luxuriant vegetation.

And the fact that the roots (*Stigmariæ*) of the forest-trees (*Sigillariæ*) of the carboniferous period are generally present, and for the most part in their natural position, in the underclay beneath each bed of pure coal, proves that those trees grew on the areas now occupied by their carbonized remains. Without, however, having recourse to the hypothesis of alternate subsidence and elevation of the land, may we not suppose that there were extensive inland areas,* depressed, like the basin of the Caspian, many hundred feet below the level of the sea, affording the shelter, warmth, and moisture required by a subtropical flora, and subjected to

* The most remarkable known instance of an area of land depressed far below the sea-level is that mentioned by Humboldt (*Cosmos*). In descending eastward from Jerusalem to the Dead Sea and the Valley of Jordan, a view is enjoyed which, according to our present hypsometric knowledge of the earth's surface, has no parallel in any other region. The rocks on which the traveller treads, with the open sky over his head, are 1312 feet below the level of the Mediterranean. Though from the revolutions which have swept over the earth's surface, and the displacements and mutations which its crust has undergone since the carboniferous period, there is but little probability that any of the coal-fields are now in the same position in relation to the sea-level as at the period of their formation, I would, nevertheless, direct attention to the following statements and remarks of the illustrious philosopher just cited:—The depth of the Coal-basin at Liege is estimated by Von Dechen at 3809 feet below the surface, and 3464 feet *beneath the level of the sea;* and that of Mons, at 5329: while the lowermost coal-strata of the Saar-Rivier (Saarbrück) are computed by the same eminent observer to descend to a depth of 21,358 feet *below the sea-level*, or 3.6 geographical miles. This is a depth below the sea equal to that of Chimborazo above it; and the temperature would be 467° of Fahrenheit if the increase be in the supposed ratio of 1° for every 54 feet of vertical depth. We have, therefore, from the highest summits of the Himalayahs to the lowest portions of the basins which contain the fossil flora of the carboniferous epoch, a vertical distance of about 48,000 feet, or $\frac{1}{435}$th of the earth's *semi-diameter*.

periodical inundations from mountain-torrents, poured down from alpine regions on which the pines and other coniferæ, associated with the arborescent ferns of the coal, may have flourished? Would not such physical conditions, modified by occasional changes in the relative level of the land and water by subterranean movements, meet the exigences of the case?

44. ZOOPHYTES AND ECHINODERMS OF THE CARBONIFEROUS SYSTEM.—We must now briefly notice the animal remains entombed in the deposits that are associated with those which have proved so rich and varied a field of botanical research. The Zoophytes and Molluscs are for the most part marine, and in a great measure confined to the limestones below the coal.

There are but doubtful evidences of the Sponges in these beds; but Foraminifera often abound. *Textularia* and *Endothyra* have been discovered by Prof. Phillips * in slices of limestone from Yorkshire and Westmoreland, and by Mr. Sorby in some mountain-limestone from Shropshire. *Nodoraria* has been found in the carboniferous rocks of Tyrone, by M'Coy; † a Nummulite-like form occurs in the mountain-limestone both of Shropshire and of Russia; ‡ and one of the most characteristic fossils of the mountain-limestone of the Lower Volga in Russia, § and of the Ohio in North America, is the *Fusulina;* white limestones and calcareous shales being almost wholly composed of this little shell (*F. cylindrica*), which resembles a grain of wheat or rice, and is allied to the *Nonioninæ.* A second species has been detected in the carboniferous limestone of the Arctic Regions, by Mr. Salter.‖

* Trans. Polytechn. Soc. Yorkshire, 1846, p. 277.

† Annals Nat. Hist. vol. xiii. p. 131.

‡ Bullet. Imp. Soc. Nat. Moscow, 1849, vol. xxii. p. 337

§ *Geology of Russia*, Pl. I. fig. 1.

‖ *Belcher's* "Arctic Voyage," vol. ii. Appendix.

The Corals* amount to very many species, chiefly belonging to the genera *Alveolites*, *Amplexus*, *Aulopora*, *Chætites*, *Clisiophyllum*, *Cyathophyllum*, *Lithodendron*, *Lithostrotion*, *Michelinia*, *Nematophyllum*, *Syringopora*, and *Zaphrentis*.

Of Bryozoa, *Fenestella* is the most common genus in this formation. The mountain-limestone swarms with *Crinoidea;* and entire beds are made up of their petrified remains, as was explained in the former Lecture (see p. 660). Elegant and abundant species of *Actinocrinus*, *Cyathocrinus*, *Platycrinus*, *Poteriocrinus*, and *Rhodocrinus* combine to characterize the carboniferous limestones and shales; but several of rarer occurrence are also found.

A singular type of Crinoideans, named *Pentremites*† (*Lign.* 181, *fig.* 7), also abounds in the mountain-limestone, both in England and America‡ (see p. 666).

Other echinoderms of a peculiar character (*Archæocidaris* and *Palæchinus*) are not unfrequent in the carboniferous limestone of Ireland and Yorkshire.

45. Shells of the Carboniferous System. — The remains of nearly 800 species of the various tribes of mollusca have been obtained from this formation in the British Isles alone.

About twenty species of bivalve shells, having close alliances with existing genera of shells living in fresh or brackish waters, and therefore indicative of their own fresh-water or estuarine origin, occur in some of the coal-measures. These fossil genera comprise *Anthracosia*,§ *Cardinia*, *Myalina*, *Mytilus*, and *Unio;* and some of the species abound in some parts of the coal-measures in extensive, though thin, beds of shale or limestone, known as "mussel-bands."

* See Milne-Edwards and J. Haime's beautiful Monograph, published by the Palæontographical Society, 1852.

† Comprised in the Blastoidean Order of the Echinodermata.

‡ Medals of Creation, vol. i. p. 297.

§ See Prof. King's interesting paper on the distinctive characters of this member of the Unionidæ, in the Annals Nat. Hist. 2nd ser. vol. xvii. p. 51.

The marine shells of the carboniferous rocks are in a great measure limited to the limestone and shales below the coal. Exceptional instances, however, have been already mentioned.* Many species of gasteropodous spiral univalves abound in some of the limestones. *Pleurotomaria* and *Euomphalus* are the most frequent; the latter is remarkable from its inner volutions being traversed by imperforate septa.† Some limpet-like gasteropods are also found, such as *Capulus* and *Patella*. A very common and characteristic univalve is the *Bellerophon* ‡ (*Lign.* 181, *fig.* 4), usually referred to the Nucleobranchiate division of the Gasteropoda.§ The most interesting Gasteropod of the coal-series is a pupa-like shell, probably a land-snail, of which one or two specimens were found, together with the remains of a little batrachian reptile, by Sir C. Lyell and Mr. Dawson, in an upright fossil tree-stump in the coal-measures of Nova-Scotia.‖ The cephalopodous shells found in the mountain-limestone of Britain and Ireland, and in the associated strata, amount to upwards of 130 species. The Ammonite of the secondary formations is in this system abundantly represented by its near ally, the *Goniatites;* ¶ and the *Nautilus* ** and the *Orthoceras* †† almost rival the Goniatite in numbers.

The *Orthoceras* (*Lign.* 181, *fig.* 12) may be described as a straight Nautilus, of an elongated and cylindrical shape, tapering to the extremity, and having entire septa, pierced by a siphuncule (*fig.* 13). The Orthoceratites are often from twenty to thirty inches in circumference at the largest extremity, and upwards of seven feet in length.

Numerous bivalves of genera closely related to, if not identical with, the existing *Avicula* and *Pecten* also occur; and other bivalves, such as *Cypricardia*, *Conocardium*, *Ed-*

* See above, p. 676. † Medals, p. 428. ‡ Medals, p. 465.
§ Woodward's "Manual of the Mollusca," p. 201.
‖ Quart. Journ. Geol. Soc. vol. ix. p. 58, pl. iv.
¶ Medals, p. 482. ** *Medals*, p. 467. †† Medals, p. 475.

mondia, *Leda*, *Modiola*, *Nucula*, *Sanguinolites*, and *Sedgwickia*.

But the most striking modification in the molluscous fauna is the abundance of extinct types of *Brachiopoda** or *Palliobranchiata*,† such as *Athyris*, *Chonetes*, *Leptæna*, *Lingula*, *Orthis*, *Productus*, *Rhynchonella*, *Spirifer*, *Strophomena*, &c. These occur in profusion; and entire beds of limestone sometimes are aggregations of the shells of these curious animals.

As we descend to the more ancient rocks, we shall find these fossils yet more prevalent; and I will, therefore, in this place offer a few remarks on the structure of this family of mollusca.‡ The small subglobular bivalves, *Terebratulæ*,§ so abundant in the chalk, are sometimes found empty, and, if the valves be carefully separated, two curious appendages are seen projecting from the hinge into the interior of the shell; these processes are the internal skeleton for the support of ciliated organs for the production of currents in the water. In the Spirifers (*Lign.* 181, *figs.* 2, 9, 11), there are two spiral appendages ‖ which are closely coiled, and are often, like the substance of the shell itself, changed into calcareous spar (*figs.* 2, 9); in specimens where the shell is removed, these organs may be seen in their original situation.

The loop-like processes observable in the interior of the shells of many of the fossil Terebratulæ are the internal skeleton, and are for the attachment of the muscular stems, or stalks of the fringed arms, or lateral prolongations of the lips of the animal. These arms, or oral appendages, are fringed with *cirrhi*, probably covered with microscopic *cilia*; and by the vibratile action of the latter minute particles of food are transmitted

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* *Arm-foot:* the spiral arms of some of these molluscs were at first supposed to serve to some extent as locomotive organs; hence this most-used name.

† *Mantle-gilled:* the animals having no special branchiæ or gills, their blood is aërated through the medium of their inner integument or *mantle:* hence this philosophically correct, but neglected name.

‡ See Owen "On the Anatomy of the Brachiopoda," Zoological Transactions, vol. i. p. 145; "Lectures on Comp. Anat." &c.; Woodward's "Manual of Mollusca," p. 209; and Davidson's "Monographs of the British Fossil Brachiopoda," published by the Palæontographical Society (especially the Introduction)

§ Medals, p. 388.

‖ ... the name of the genus (coil-bearing).

towards the mouth. In *Rhynchonella psittacea*, a recent species (*Lign.* 181, *fig.* 6), two spiral arms, fringed at their outer margins, are seen to arise from processes having the form of lamellar plates; these oral arms are quite

LIGN. 181.—SHELLS AND CRINOIDS, CHIEFLY FROM THE PALÆOZOIC STRATA.

Mountain-limestone. *Fig.* 1. Productus punctatus. 2. Spirifer trigonalis. 4. Cast of Bellerophon cornu-arietis. 5. Euomphalus pentangulatus. 7. Pentremites ellipticus. 9. Spirifer trigonalis, showing one of the spiral processes *in situ*. 10. Spirifer triangularis. 12. Orthoceras laterale. 13, Septum of the same.

Wenlock limestone. *Fig*, 3. Leptæna depressa. 8. Atrypa reticularis. 11. Spirifer elevatus.

Recent. *Fig*. 6. Rhynchonella psittacea, showing the fringed spiral brachia or arms, and one of them artificially extended; the perforated valve and the lobe of the mantle are removed. *Fig. a b*, a portion of the fringe of cirrhi, magnified.

free, except at their origins; when unfolded, they are twice as long as the shell, and in their natural state of contraction are disposed in six or seven spiral gyrations, which decrease towards their extremities. It has been conjectured, that, as the stems are hollow from one end to the other, and filled with fluid, this might be acted upon by the spirally disposed muscles composing the walls of the canal, and forcibly injected towards the extremity of the arms, which would be thus unfolded and protruded. None, however, of the living specimens of this animal observed by Mr. Barrett,* in 1855, protruded their arms; but these organs were extended just so much that the cirrhi, when unbent, came as far as the margin of the shell.

The arrangement of the fringed arms in the known living Brachiopoda is generally either more or less perfectly spiral, sigmoid, looped, or folded. In the fossil genera *Spirifer*, *Athyris*, *Merista*, *Retzia*, *Uncites*, and *Atrypa*, the internal, calcareous, spiral appendages were evidently the supports of perfectly spiral arms. If indeed the arms of *Rhynchonella* were so supported, that genus would present the same structure as that of *Atrypa*, and a close analogy to that of the *Spiriferidæ*.

46. Crustaceans and Insects.—With the layers of fresh-water shells that are intercalated in some of the coal-deposits, there are a few species allied to water-fleas, *Cypridæ*. They occur abundantly in the Nova-Scotian and some of the Pennsylvanian coal-measures; also in the Shrewsbury, Ashby-de-la-Zouch, Border-country, and Burdie-House coal-strata. In the last, and near Glasgow, two species of a peculiar entomostracous crustacean, *Eurypterus*,† one of which is twelve inches long, have been discovered by Dr. Hibbert.

Dithyrocaris ‡ is another peculiar form of the lower tribe of crustaceans not uncommon in some of the carboniferous strata of Ireland and Scotland.

In the ironstone-nodules of Coalbrook Dale, the remains of small crustaceans sometimes form the nucleus, and Mr. Prestwich § discovered some in a good state of preservation (*Lign.* 182). Some of these crustaceans are referable to the *Limu-*

* Annals Nat. Hist. 2nd ser. vol. xvi. p. 257.

† Medals, p. 524. ‡ Medals, p. 525.

‡ Geol. Transact. 2nd ser. vol. v. p. 41.

§ The chemical changes which have taken place in the carboniferous strata, and led to the formation of the bands and nodules of ironstone, are thus explained by Sir H. de la Beche:—The argillaceous lus, or King-crab; a genus which is abundant in the seas of India and America. The Limulus is one of the lower Crustacea (Entomostraca), and has a distinct carapace or buckler, and the last segment is prolonged into a point or style; it has two eyes in front of the shield, and the gills are disposed on lamelliform processes.

LIGN. 182.—LIMULUS FROM COAL-BROOK DALE. (*Limulus trilobitoides.*)*

iron-stones are formed of carbonate of iron, mingled mechanically with earthy matter, commonly corresponding with that constituting the shales with which they are associated. Mr. Hunt, of the Museum of Economic Geology, instituted a series of experiments to illustrate the production of these clay-ironstones, and he found that decomposing vegetable matter prevented the further oxidation of the protosalts of iron, and converted the peroxide into protoxide of iron, by taking a portion of its oxygen to form carbonic acid. Under the conditions necessary for the production of the coal distributed among the sand, silt, and mud, the decomposition of the vegetable matter would necessarily form carbonic acid, among other products. This carbonic acid, mixed with water, would spread with it over areas of different dimensions according to circumstances; forming salts and meeting with the protoxide of iron in solution, it would unite with the protoxide, and form a carbonate of iron. The carbonate of iron in solution would mingle with any fine detritus which might be held in mechanical suspension in the same water; and hence, when the conditions for its deposit arose,—which would happen when the needful excess of carbonic acid was removed,—the carbonate of iron would be thrown down, intermingled with the mud; and, if not in sufficient quantity to form continuous layers, would aggregate into nodules, and be arranged in planes amid the sediment.—*Memoirs of the Geological Survey of Great Britain*, vol. i. p. 185. See also Prof. W. Rogers on the Carbonate of Iron in the Coal-Measures, Silliman's Journal, vol. xxi. p. 339; Mr. Binney on the Origin of Iron-stones, Mem. Lit. Phil. Soc. Manchester, vol. xii. p. 31; and a paper by Dr. Hooker and Mr. Binney on some limestone-nodules, in the bituminous coal of the Lancashire coal-field; Proceed. Roy. Soc. *vol. xii. p. 188.*

* *Buckland, Bridg. Treat. p. 396.*

It is in the carboniferous system that we first meet, in a descending order, with vestiges of the extinct family of crustaceans called Trilobites* (*Griffithides*, *Phillipsia*, &c.); but, as these animals are especially characteristic of the older rocks—the Silurian, I shall reserve a particular notice of them for the next discourse.

The higher Crustacea are still but little known in the coal-rocks. The *Gampsonyx*,† however, of the Saarbrück coal, combines some characters now found in the Amphipods and the Decapods; and the *Pygocephalus* ‡ of the Manchester coal-shales, another rare form, is referable either to the lower Decapods or to the Stomapods.

Insects.—The remains of insects belonging to several genera have been found in the carboniferous series of England and Europe. From the ironstone-nodules of Coalbrook Dale, several species of beetles, related to the *Curculio* or diamond-beetle, have been obtained. In a nodule from the same locality I discovered the wing of a large neuropterous insect, closely resembling a species of living Corydalis of Carolina.§ The coal-measures of South Wales have also yielded insect-remains.‖

Numerous specimens of orthopterous, neuropterous, and coleopterous insects have been described by F. Goldenberg ¶ from the coal-basin of Saarbrück, in Rhenish Prussia, whence so many other interesting fossils have been obtained.

Fossil Scorpion.—Not only are the remains of insects imbedded in the coal-strata, but also those of animals to which they served as food. A fossil *Scorpion* has been discovered by Count Sternberg in carboniferous argilla-

* Medals, p. 532.

† Jordan and von Meyer, Palæontographica, vol. iv. p. 1, pl. i.

‡ Huxley, Journ. Geol. Soc. vol. xiii. p. 363, pl. xiii.

§ Medals, p. 554. This specimen is now in the British Museum.

‖ In the collection of the Rev. S. Lucas, F.G.S.

¶ Palæontographica, vol. iv. p. 17, plates iii. to vi.

ceous schist, at Chomle, S.W. of Prague, in Bohemia.* This fossil is about two inches and a half long, and is imbedded in coal-shale, with leaves and fruits. The legs, claws, jaws, and teeth, skin, hairs, and even portions of the trachea, or breathing apparatus, are preserved. It has twelve eyes, and all the sockets remain; one of the small eyes and the left large eye retain their form, and have the cornea, or outer skin, preserved in a corrugated or shrivelled state. The horny covering is also preserved; it is neither carbonized nor decomposed, the peculiar substance of which it consists, *elytrine*, having resisted decomposition and mineralization.

47. Fishes of the Carboniferous System.—The fishes of the coal† are of the placoid and ganoid groups (see p. 352): and several of the genera have not been found in any other system; all of these have the heterocercal form of tail (see p. 531). Sixty genera have been determined from the carboniferous strata of the British Isles. I can only allude to a few of the most characteristic.

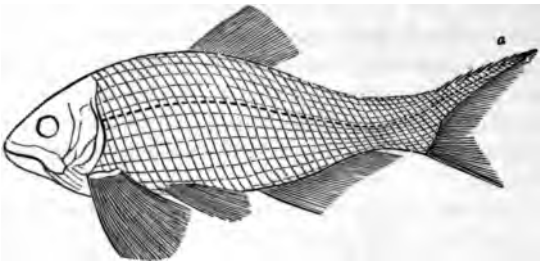
Amblypterus.—This is a genus restricted to the coal-measures, and is characterized, as its name implies, by very large and wide fins composed of numerous rays. The scales are rhomboidal and finely enamelled; and the teeth are small, numerous, and set close together like the hairs of a brush; indicating that these fishes fed on decayed sea-weeds and soft animal substances. The tail is a good example of the heterocercal type. A restored outline of the fish is given in *Lign.* 183, from M. Agassiz's great work, the "Poissons Fossiles." Four species have been found in no-

* See Verhandl. Gesell. vat. Mus. Böhmen, 1835, p. 35; Dr. Buckland's Bridgewater Treatise, plate 46, p. 406, *et seq.*

† See some interesting remarks on the fishes of the North American coal-beds, by Mr. Newberry, in the Edinb. New Phil. Journ. New series, vol. v. p. 364; and by Messrs. Worthen and Agassiz, ibid. p. 367.

dules of ironstone at Saarbrück, on the borders of Lorraine; and at Newhaven, near Leith.

Megalichthys.—Of the remarkable group of fishes termed *Sauroid*,* the remains of two genera have been discovered in the strata at Burdie House by Dr. Hibbert, and subsequently in several other localities. The *Megalichthys* was covered with enamelled, quadrangular, finely granulated scales, very thick, and nearly an inch wide. The head was protected by strong enamelled plates. It had very large teeth, which were conical, hollow, and striated. This fish was from three to four feet in length.



LIGN. 183.—RESTORED FIGURE OF THE AMBLYPTERUS; A HETEROCERCAL FISH PECULIAR TO THE CARBONIFEROUS SYSTEM: *one-sixth the nat. size.*

a, The upper lobe of the tail, into which the vertebral column is prolonged.

Holoptychius.—This is a genus of gigantic sauroid fishes, some species of which attained a length of thirty feet. The scales are thin and nearly circular, the upper surface corrugated in ridges, and from one to five inches in diameter. The plates covering the head have a shagreen-surface with irregular ridges. It has large conical sauroid teeth of great density; and numerous long slender teeth.

Cestracionts.†—Remains of numerous extinct species of

* *Medals*, p. 615. † Medals, p. 583.

fishes related to the recent Cestracion, or Port Jackson shark, are found in some beds of the mountain-limestone, especially near Bristol, and at Armagh, in Ireland. At the latter place Admiral Theobald Jones has collected vast numbers of beautiful specimens of teeth (both of the cutting and the crushing forms), and of fin-bones or spines from the hard grey marble; some of them being of large size.*

48. Reptiles of the Carboniferous Period.—Not many years since, reptilian remains not having been then found in the carboniferous rocks, it was supposed that the earliest date of the existence of reptiles on this earth was that of the Permian rocks. Now, however, we have both bones and foot-tracks of reptiles not only in the coal-measures and in the mountain-limestone, but in the Devonian strata.

The *Archegosaurus*,† a sauro-batrachian of close relationship with the *Labyrinthodon* (see p. 552), has left abundant remains in the coal-fields of Rhenish Prussia,‡ the *Parabatrachus* § occurs in the coal of Scotland; and the allied *Dendrerpeton*,‖ and the labyrinthodontoid *Baphetes*,¶ have been found in the coal-measures of Nova Scotia.

Cheirotherian foot-tracks of reptiles have been discovered on some of the shales of the coal-measures in the United States; ** and in the red shales at Pottsville, Pennsylvania, which Dr. Isaac Lea refers to the carboniferous series, but which the State-geologists, the Professors W. B. and H. D.

* A very magnificent series of these fossils has been presented to the Geological Society's Museum, by Admiral Jones, F.G.S.

† Medals, p. 745.

‡ See Hermann von Meyer's elaborate Memoir on the Archegosauri and allied genera, in the *Palæontographica*, vol. vi.

Quart. Journ. Geol. Soc. vol. ix. p. 67.

‖ *Ibid.* p. 58; and Lyell's Manual, 5th edit. p. 405; Medals, p. 746.

¶ Quart. Journ. Geol. Soc. vol. x. p. 207, and vol. xi. p. 8.

** See above, p 570; and Lyell's Manual, 5th edit. p. 401.

Rogers, determine to be the local representative of the lower portion of the Mountain-limestone, both Dr. Lea and Prof. H. D. Rogers have found foot-tracks resembling those of thin-toed saurians.*

Similar tracks to the last mentioned have been found on the coal-shale of the Forest of Deane; and Cheirotherian footprints on a gritty carbonaceous stratum, forming a "roof" of the coal, in one of the coal-mines at Dalkeith,† which are worked in the Mountain-limestone series.

Here then are evidences enough, and doubtlessly further researches will contribute more, of the terrestrial and amphibious vertebrated animals, which, crawling among the tangled swampy jungles, and on the oozy surface of the shores, inhabited the lands that were clothed with the luxuriant vegetation of the carboniferous flora.

49. Climate of the Palæozoic ages.—The cause of the difference between the natural climates now prevailing over extensive zones of the earth's surface, and those which the organic remains discovered in many of the older strata lead us to conclude have formerly subsisted during very long periods of time—and apparently over the greater part of its whole extent—is one of those geological problems the solution of which is not at present wholly within our reach. Unable to account for such a distribution of an apparently high climatorial temperature—a diffusion of heat and light so greatly at variance with that which has prevailed during the human epoch—the mind naturally endeavours to penetrate the mystery by a reference to physical causes extraneous to our planet. But, as yet, astronomy has afforded no satisfactory elucidation of the subject.

A variation in the eccentricity of the earth's orbit, and a change in the position of the tropical zone, on account of the precession of the equinox

* *Sauropus primævus*, Lea, Transact. Amer. Phil. Soc. vol. x. 1852.

† Hugh Miller's Testimony of the Rocks, p. 78. These specimens are deposited in the Museum of the Geological Survey, in Jermyn Street.

—both changes, which, though extremely slow, are appreciable—have been brought forward to account for the phenomena under review.

From the diminution of the eccentricity of the earth's orbit round the sun, by which the ellipse is in state of approach to a circle, the annual average of solar radiation is on the decrease; and therefore, as a general cause, and one affecting the mean temperature of the whole globe, and the effect of which is both inevitable and susceptible of exact estimation, it is deserving consideration.*

In assuming a temperature in northern regions sufficient to support a quasi-tropical vegetation, it must, too, be borne in mind, that light is as indispensable as heat for the luxuriant growth of tree-ferns, conifers, cycadeæ, &c.; and, by analogy, for the gigantic club-mosses and ferns of the carboniferous period. The absence of light for weeks or months would probably be fatal to most of the existing tropical forms of vegetation. It is therefore as necessary to account for the presence of light as for a high temperature in the northern regions, where fossil plants indicate the former genial influence of a warm climate and sunny skies during the carboniferous era.

To account for the existence of regions capable of supporting such a flora as that of the coal-measures in northern latitudes, it has been argued by an American author,† that the changes on the earth's surface which have produced the successive strata and organic remains, as far as these are regular, are attributable to the progress of the perihelion point around the ecliptic: that by the precession of the equinoxes, and the progress of the perihelion-rotation of the earth's orbit, a great uniform zone of tropical climate, which formerly surrounded the globe in a different course from that of the present tropics, has by very slow degrees changed its position, and that the present tropical zone succeeds it in a continued change of position.‡

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* Sir J. F. W. Herschel, on the Astronomical Causes which may influence Geological Phenomena. Geol. Trans. 2nd ser. vol. iii. p. 293.

† "An Essay on Organic Remains as connected with an ancient Tropical Region of the Earth." By T. Gilpin, Philadelphia, 1843.

‡ The subject of hypothetical causes of conditions and changes of temperature in former periods of the earth's history has been also treated of by the late Mr. W. D. Saull, in his "Essay on the Connexion between Astronomical and Geological Phenomena," 8vo, London, 1853; and by Mr. Evan Hopkins, in his book entitled, "On the Connexion of Geology with Terrestrial Magnetism." 8vo, London, 1851.

Whether either or both of the above-named causes may be regarded as applicable or adequate to have produced any of the contemplated effects, I must leave to the astronomers to determine. There is, however, another cause, first suggested by Sir C. Lyell, that possesses all the essential requisites of a *vera causa;* and that is the varying influence of the distribution of land and sea over the surface of the earth.*

A change of such distribution in the lapse of ages, by the degradation of the old lands, and the elevation of new, is a demonstrated fact; and the influence of such a change on the climates of particular regions, if not of the whole globe, is a perfectly fair conclusion, from what we know of continental, insular, and oceanic climates by actual observation. "Here, then," observes Sir John Herschel, "we have, at least, a cause on which a philosopher may consent to reason; though whether the changes actually going on are such as to warrant the whole extent of the conclusion, or are even taking place in the right direction, may be considered as undecided, until the matter has been more thoroughly examined." † Another astronomical source of periodical variability in the general temperature of the earth's surface has been brought forward by Sir John Herschel,‡ who, instancing the observed variability in the luminosity of certain stars, suggests the possibility that the sun of our system may in the course of ages be subject to similar phases of augmented or diminished energy; and that such variability in the periods contemplated by Geology may have given rise at one epoch to a general equatorial climate, and at another to one far below the general temperature that now prevails.

Two other supposed causes of the existence of a general warm climate in the earlier geological periods may be here mentioned: namely, 1. *Central heat*, supposed to be the remains of a former and very much greater heat, which has been gradually diminishing during some indefinite period of time: 2. The passage of the solar system through some region

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* Highly important remarks on the relative extent of land and sea in the palæozoic ages were found in the 18th chapter of Sir Roderick Murchison's "Siluria."

† "Discourse on the Study of Natural Philosophy," p. 146.

‡ In his magnificent work, entitled, "Result of Astronomical Observations made at the Cape of Good Hope," 1847, p. 351.

of stellar space, of which the temperature, owing to stellar radiation, is much greater than that in which it is now placed.

Both of these hypotheses have been treated, especially in reference to the Glacial period in the Tertiary age, in a masterly manner by Mr. W. Hopkins, of Cambridge, in the Geological Society's Journal.* With regard to the first, he remarks, that the effect on the superficial temperature due to this cause may have been formerly of any amount, but is now reduced to within 1-20th of a degree of Fahrenheit of that ultimate limit to which it would be reduced in an indefinite period of time, supposing the external conditions under which the earth is now placed—such as the amount of radiation from the sun and stars, and the state of the atmosphere—to remain as at present. Poisson has calculated that it would require 100,000 millions of years to reduce the present temperature by about 1-40th of a degree of Fahrenheit. It is probable, therefore, that many millions of years must have elapsed since the central heat can have elevated the earth's superficial temperature by a single degree, and it is only to the more remote geological periods that we can refer for any very sensible change in the climatal conditions of our globe due to this cause. Prof. Ramsay, following out this line of argument, has shown † that the internal heat of the earth has exerted no important climatal influence during any of the geological periods, from the Silurian times downwards.

Of the second hypothesis, which was suggested by Poisson, Mr. Hopkins remarks that it involves the necessity of supposing a totally different distribution of the group of stars to which the sun should belong, or the near approach of the solar system to some individual star; either supposition being probably inconsistent with the integrity of the solar system as it now exists. At all events, this hypothesis would not account for the changes of climatal temperature that have taken place in comparatively late geological times.

The soundness of the theoretical views of the probable causes of climatal changes suggested by Lyell is well elucidated by Mr. W. Hopkins, in the Memoir above quoted, by an exposition of the probable configuration of the European and North American areas in the Glacial period;—when, according to Mr. Hopkins, the absence of the Gulf-stream, with its influences upon the western coast of Europe, may be assumed,

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* See his Memoir, "On the Causes of Change in the Earth's Superficial Temperature," Journ. Geol. Soc. vol. viii. p. 56; and his Presidential Address for 1852, *ibid.* p. lvii.

† *Quart. Journ. Geol. Soc.* vol. xi. p. 203.

together with the submergence beneath the sea of a large portion of Northern and Western Europe.*

50. Retrospect; Botanical epochs.—I will conclude this discourse with a review of the prevailing botanical characters during the principal geological epochs.

Count Sternberg, M. Adolphe Brongniart, Dr. Lindley, and other eminent botanists have adduced some interesting generalizations from the fossil floras of the various formations: and although conclusions of this kind must be regarded in the nature of shifting hypotheses, and will require to be modified by new discoveries—for all the fossil species at present known amount only to about two thousand,† yet the characters of the floras of certain formations differ in so striking a manner from those of others, that it is very improbable that many of the essential features have been lost.

The flora of the ancient world may be regarded as characteristic of three distinct eras. The first period, termed by Brongniart "the age of Acrogens," comprehends the earliest strata in which traces of vegetation appear,‡ and includes the Carboniferous. The plants of this epoch consist of fucoids, ferns of various kinds in great abundance, coniferous trees related to species of warm climates, cycadaceæ, a few flowering plants,§

* See also A. Henfrey's "Vegetation of Europe," for some valuable remarks on this subject.

† Prof. Göppert, in 1845 (Rep. Brit. Assoc.), computed the number of species of fossil plants then known to amount to nearly 2000; and stated their distribution in the strata to be as follows:—

In the palæozoic strata below the Coal, principally in the Devonian	52	Triassic	86
Carboniferous	819	Oolitic	234
Permian	58	Wealden	16
		Cretaceous	62
		Tertiary	454

‡ Lycopodiaceous seed-vessels and fragments of wood, found in the Upper Silurian Tilestones, are the oldest-known *terrestrial* plant-remains.—H. E. Strickland, *Quart. Journ. Geol. Soc.* vol. ix. p. 10; and J. W. Salter, *ibid.* vol. xiv. p. 76.

§ The *Antholites* of the coal-measures. Some, at least, of these may have belonged to monocotyledonous, or even dicotyledonous, flowering plants, such as the Bromeliaceæ or the Lobeliaceæ. See Lindley and great woody equisetaceæ, gigantic lycopodiaceæ, and trees (Sigillariæ) whose precise relations to known forms is not determined. In this flora the tree-ferns predominate, and the general type of the vegetation is analogous to that of the islands and archipelagos of tropical and subtropical climates

The second period (that of Gymnosperms) extends from the Triassic or New Red to the Chalk inclusive, and is characterized by the occurrence of many species of cycadaceæ and coniferæ, a few palms, and, in the Lias,* of a few, but in the Cretaceous beds (see vol. i. p. 329) of many, dicotyledonous plants; while the proportion of ferns is much less than in the preceding period, and the lycopodiaceæ and equisetaceæ are fewer, and present forms different to those of the carboniferous strata. A flora of this nature corresponds with that of the coasts and maritime districts of New Holland and the Cape of Good Hope.

The third epoch (Brongniart's "age of Angiosperms") is that of the tertiary, in which the dicotyledonous tribes present themselves in great abundance; the cycadaceæ are rare, the ferns in diminished numbers, and the coniferæ and palms numerous.

In the latest tertiary strata are imbedded the remains of trees and plants of species still living in the countries where these deposits occur; and so also in the beds in actual progress of formation, the most delicate vegetable remains are preserved; thus, in the lacustrine marls of Scotland the leaves and seed-vessels of the Charæ are found in a state of fossilization scarcely distinguishable from the gyrogonites of the tertiary strata of the Paris basin, and of Headon Hill, or of the Purbeck beds of Dorsetshire.

From this review of the botanical epochs which the present state of geological knowledge enables us to establish, we perceive that, from the most ancient formation in which traces of vegetation remain, the sea has supported the usual forms of marine plants; and that on the land, ferns, other cryptogamia, and coniferæ have existed through periods of indefinite duration to the present time; the most striking and important differences in the ancient and modern floras being the numerical preponderance of the cryptogamia in

Hutton's "Fossil Flora;" Morris, in Prestwich's Memoir on Coalbrook Dale, Geol. Trans. 2nd ser. vol. v.; and Hooker, in Lyell's "Manual" (Supplem. 1857).

* *Buckman, Quart. Journ.* Geol. Soc. vol. vi. p. 517.

the former, and of the dicotyledonous tribes in the latter,—and the more extensive geographical range of the sam species of plants during the Carboniferous era. The theor of the progressive development of creation receives no sup port from the state of vegetation in the early geologica epochs; not only the most perfectly organized of the crypto gamic class, but the coniferæ * also are among the oldest c fossil plants.

The absence of nearly all vegetable forms in the mos ancient fossiliferous rocks must not be regarded as a proo that the floras of those remote periods were thus sterile the only legitimate inference, in the present state of ou knowledge, is, that the circumstances under which thos strata were accumulated were unfavourable to the envelop ment and preservation of terrestrial plants. We have see that the grand fundamental distinctions of the vegetabl kingdom existed in the early secondary ages, a fact in ac cordance with what we observed in the animal kingdom and thus the same unity of purpose and design is manifest in all the varied forms of organization that lived on our planet through the vast periods of time which geological investigations have enabled us to scan.

* See Dr. Hooker's opinion of the rank of conifers in the vegetable kingdom, Lyell's "Manual," 5th edit. p. 373.

LECTURE VIII.

PART I.—THE DEVONIAN, SILURIAN, AND CAMBRIAN FORMATIONS.

1. INTRODUCTORY.—In the previous Lecture the Floras of the palæozoic ages constituted the principal subject of investigation. We examined the primeval forests of coniferæ, the groves of arborescent ferns, and jungles of Sigillariæ and Calamites, which clothed the surface of the soil in that remote period of the earth's physical history. The insects which fluttered among the tropical vegetation of the islands and continents of those periods, the reptiles of the swamps, and the fishes and crustaceans which inhabited the seas and rivers, were brought in review before us, and we contemplated their extraordinary forms and organization, as preserved by those natural processes

> "Which turned the ocean-bed to rock,
> And changed its myriad living swarms
> To the marble's veined forms." MRS. HOWITT.

We now advance another stage in our eventful progress; and again we have *to investigate* deposits that have been accumulating for innumerable ages in the profound depths of seas fed by rivers and streams charged with the detritus of the countries over which they flowed, and imbedding the remains of the plants and animals that existed at the period of their formation. Again we shall find new forms of existence presented to our notice, differing from, but bearing an analogy to, the inhabitants of the waters which deposited the marine strata of the most ancient beds previously examined, yet altogether dissimilar from those of modern eras. In vain may we seek for the remains of the mammalia of the Tertiary period,—of the molluscs, fishes, and reptiles of the Chalk,—of the colossal oviparous quadrupeds of the country of the Iguanodon,—of the dragon-forms of the Oolite,—of the fish-like lizards of the Lias,—or of the tropical forests of the Carboniferous period,—all have disappeared; and, as the traveller, who ascends to the regions of eternal snow, gradually loses sight of the abodes of man, and of the groves and forests, until he arrives at sterile plains, where a few stunted shrubs alone meet his eye,—and, as he advances, even these are lost, and mosses and lichens remain the only vestiges of organic life,— and these too at length pass away, and he enters the confines of the inorganic kingdom of nature;—in like manner the geologist, who penetrates the secret recesses of the globe, perceives at every step of his progress the existing types of animals and vegetables gradually disappear, while the relics of other creations teem around him; these in their turn vanish from his sight,—other new strange modifications of organic structure supply their place,—these also fade away,—traces of animal and vegetable life become less and less manifest, until they altogether disappear; and he descends to the crystalline rocks, where all evidence of organization is lost, and the granite, like a pall thrown over the relics of the former world, conceals for ever the earliest scenes of the earth's physical drama.

2. THE DEVONIAN SERIES.—I purpose in this division of the present Lecture to consider the characters and relations of the remaining systems of fossiliferous deposits, namely, the *Devonian*, *Silurian*, and *Cambrian* : all the still more deeply seated rocks, so far as our present knowledge extends, being destitute of any traces of organization, whether of the animal or of the vegetable kingdoms.

The Devonian series, formerly called the *Old Red Sandstone* (p. 205), lies immediately beneath the Carboniferous Limestone, and is largely developed in Devonshire and Cornwall, in Pembrokeshire, Monmouthshire, and Herefordshire; in the south-east border of the Grampians, and over a large portion of the north-eastern part of Scotland. In Ireland there are extensive areas of strata of Devonian age, in the north, south, and central districts. This series consists of many alternations of conglomerates, shales, and sandstones, in various states of induration. The conglomerates are formed of quartz-pebbles, water-worn fragments of slate and other rocks, cemented together either by an argillaceous or a silicious paste, coloured more or less deeply red by peroxide of iron. The quartz has been chiefly derived from the vein-stones of the old slate-rocks. These strata have evidently resulted from the degradation of ancient crystalline and schistose rocks; and have been originally accumulated in the state of pebbles, sand, and mud.

In Scotland, where the Devonian series was first characterized by being found to contain many peculiar fossils, and where it is of vast thickness, it will probably always be known by its first name of "Old Red Sandstone." In Devonshire it contains shells of a character intermediate to those of the Silurian, on the one hand, and those of the carboniferous rocks on the other, and none of which are known to occur in Scotland. The Devonian or Old Red strata were therefore identified first, from their geological position, by Sedgwick, Murchison, and Lonsdale.* Subsequently the two first-mentioned of these authors compared the Devonian of Britain with the infracarboniferous rocks of the Rhine.† Lastly, the identification of the group as really one, both by position and organic contents, was established by the survey of Russia, when Sir R. Murchison, Count Keyserling, and M. de Verneuil demonstrated that the ichthyolites of the "Old Red" of Scotland, including many of the

* Geol. Trans. 2nd ser. vol. v. p. 633, and p. 721.

† Geol. Transact. 2nd ser. vol. vi. p. 221.

very same species, and the shells of the Devonian beds of the south of England, are congregated in the same masses of sand and shale.*

Whilst there is no doubt of the marine origin of the coralliferous and shelly Devonian limestones and shales of Devon, Belgium, Germany, and Russia, there is a difference of opinion existing as to whether the Old Red strata of Scotland, Ireland, and Hereford have been accumulated in marine or in fresh water,—along the margins of a sea, or in great lakes.†

The fossils, so far as the British Isles are concerned, do not decide the question. The Old Red fishes may have been inhabitants of rivers and lakes, like their modern allies, the Bony-pikes of the North American waters, and the Bichirs of the Nile. The local abundance of plant-remains merely indicates, in some cases, the close proximity of land; and in others, probably, the presence of weedy shallows. The only shell-like fossil in the Caithness schists is undescribed, and may be either a Posidonomya, a Cyclas, or an Estheria. On the other hand, the peculiar and characteristic crustacean of the Forfarshire flagstones (the Pterygotus) is associated with some marine shells in the "Tilestones" of Lesmahago and Ludlow (the passage-beds between the Silurian and the Old-Red); though in the Yellow Sandstone of Ireland (Upper Devonian or Lower Carboniferous) it accompanies the probably freshwater mollusc, *Anodonta Jukesii.*

Although usually the conglomerates are supposed to have been the result of an agitated sea acting on the lately upheaved slate-rocks, yet Mr. Godwin-Austen regards these great conglomerate-beds as not being more than equivalent to the enormous shingle-deposits of Lake Superior, and refers to the fact that the whole extent of the Old Red series of Great Britain and Ireland is not equal to the area of the North American lakes. The outflow of the fresh water of the hypothetical Old Red lake-system would carry its fishes (which might also have been of estuarine habits) into the sea-deposits of the period; and thus, in Mr. Godwin-Austen's opinion, account for the intermixture of the Scottish fishes with marine shells in the Devonian strata of Russia. In North America, the Catskill or Old Red Sandstone is rich with the characteristic fish-remains *Holoptychius* and *Asterolepis*, but yields only two kinds of shells,—of the doubtful genus *Cypricardites* (Vanuxem). Important objections to this hypothesis, however, are advanced by Sir Roderick Murchison, in "Siluria."‡

* See also "Siluria," p. 264.

† See Godwin-Austen's remarks, Quart. Journ. Geol. Soc. vol. xi p. 51, &c

‡ "Siluria," p. 259, &c.

3. SUBDIVISIONS OF THE DEVONIAN SYSTEM: HEREFORDSHIRE AND IRELAND.—The uppermost beds of this system, for the most part, dip conformably beneath the mountain-limestone, or other members of the carboniferous series, and the lowermost pass into strata that belong to the upper member of the Silurian series. For the convenience of study, the deposits comprised in this formation in Herefordshire and the neighbouring counties are subdivided into two groups:—

I. QUARTZOSE CONGLOMERATES, SANDSTONES, AND SHALES. The sandstones are often either of a deep chocolate-red or greenish colour. The shales partake of the same tints, but are frequently mottled with blotches of red and green. Fishes of the genus *Holoptychius* and plant-remains.

II. FLAGSTONES, SHALES, AND CORNSTONE. Sandy flagstones, with intercalated red and greenish shales, containing irregular bands of concretionary limestone, provincially termed "cornstone.' Abundant remains of *Cephalaspis* and other peculiar fishes.

[This group passes into the Upper Silurian "Tilestones;" reddish, grey, and yellowish shales and fissile sandstones, which were formerly grouped with Devonian strata, but are now recognised as passage-beds between the two series, though most nearly connected, as to their zoological contents, with the Silurian.*]

The total thickness of this system in Herefordshire and South Wales is estimated by Sir R. Murchison at about [illegible]00 feet; and in Brecknockshire it constitutes the loftiest mountains of South Britain.†

The red conglomerates of this system are well displayed on the right bank of the Wye,‡ from Monmouth to Tintern Abbey (*Medals*, p. 865): and the Devonian sandstone and conglomerate form the base of the Mountain-limestone at the embouchure of the Avon, and the central nucleus or axis of the Mendip Hills (p. 522).

* See Quart. Journ. Geol. Soc. vol. xiii. p. 290.

† "Silurian System," p. 170, &c.; and "Siluria," p. 242.

‡ For the section of the Old Red strata of the Wye, see Phillips's "Manual of Geology," 1856, p. 141.

In Ireland there are several straggling exposures of reddish sandstones and conglomerates, in the southern, central, and northern districts.* These sandstones are overlaid at places by the "yellow sandstones" and "carboniferous slates." †

4. Devonian strata of Devonshire and Cornwall.—In the south of Devonshire, in many places dipping northward towards and beneath the anthracitic or culmiferous shales and limestones (p. 697), there is an extensive series of strata composed of green chlorite-slates, alternating with quartzose schists and sandstones, with blue and grey limestones, which pass into, or are associated with, red sandstones and conglomerates. Many of these beds abound in organic remains. These slaty rocks of Devonshire were formerly regarded as belonging to the earliest or most ancient fossiliferous strata—the *Transition rocks*, as they were termed, until the labours of Professor Sedgwick and Sir R. Murchison, aided by the palæontological research of Mr. Lonsdale, ascertained their true position and relations, and the unity of type which prevails in the organic remains of the entire system, in places very distant from each other, and under very dissimilar conditions of mineral character. The Devonian strata of South Devon extend westward into Cornwall, and the beautiful coralline marbles of Bab-

* See Griffith's Geol. Map of Ireland; and the Map accompanying Mr. Godwin-Austen's Memoir in the Geol. Journ. vol. xii. p. 46.

† See Portlock's "Report on Londonderry," &c.; Report Brit. Assoc. 1843, rep. sect. p. 42, and p. 47; *ibid.* 1852, sect. pp. 43, 47, and 51; Mr. Kelly's paper in the Journ. Geol. Soc. Dublin, vol. xii. p. 115; and particularly Portlock's Presid. Address, 1857, Geol. Soc. Journ. vol. xiii. p. 120. To this late summary, by Gen. Portlock, of the labours of geologists among the Carboniferous and Devonian rocks of Ireland, the reader is especially referred for a philosophical review, not only of the relations of *these rocks*, but of the principles by which geologists should be guided in *working out* the correlation of presumed equivalent deposits in different *districts*. See also Austen, Rep. Brit. Assoc. 1838, sect. p. 93.

bicombe, Torquay, &c. (pp. 650 and 652) belong to this formation.

In North Devon * also there are thick series of gritty, sandy, and shaly rocks, coming out from under the black anthraciferous strata of the central district, and presenting many characters in common with the Devonian rocks of South Wales, from which they are separated by the Bristol Channel.

From careful and extended examinations of these rocks and their fossils in North and South Devon and in Cornwall, a serial order has been recognised, according to which the northern and southern bands of strata are more or less uniformly arranged, although great differences in their mineral composition and in the variable abundance or paucity of fossils, and the frequent metamorphic changes the rocks have undergone, have made this a difficult study.†

Beneath the culm-limestones and black shales with *Posidonomyæ*, succeed—

(1.) The *Barnstaple* or *Petherwin* group of strata; chiefly consisting of shales and sandstones, associated with a limestone containing a peculiar cephalopod, the *Clymenia*, of the Nautiloid family. These beds contain numerous plant-remains (*Aspidaria*, &c.), and comprise a series of strata (the Pilton group) which are the equivalents of the "Yellow Sandstones" of Ireland and the Boulonnais. They constitute the beds of passage between the Carboniferous to the Devonian systems, being very closely related by conformability and fossils to the former. This group is equivalent also to the *Cypridinen-schiefer* and *Clymenien-kalk* of Germany.

* See the description of a section across North Devon, in "Siluria," p. 256.

† Sedgwick, Murchison, Lonsdale, Austen, De la Beche, Phillips, Sharpe, Giles, Peach, Pattison, and many others have elucidated these strata and fossils in the publications of the Geological Societies of London and Cornwall, and in other works.

(2.) The *Ilfraçomb* or *Plymouth* group, comprising the rich coral-limestones of South Devon: the equivalent of the *Eifelian* group of the Devonian rocks on the Rhine, containing *Stringocephalus Burtini*, *Brontes flabellifer*, and *Calceola sandalina*, as typical fossils.

(3.) The *Linton* or *Ashburton* group; representing the Wissenbach-slates of the Rhine, with *Pleurodictyum problematicum*.

Cornwall principally consists of "Devonian" strata, with metamorphic schists or slates (*killas*), and great masses and numerous dykes (*elvans*) of igneous rocks; but Silurian * or Cambrian † fossils have been detected in the schists and quartzites of two of the southern headlands (Nare Head and the Dodman).

The *killas* are argillaceous strata, probably of "Devonian" age, that have been indurated by metamorphic action, like those of Scandinavia and the Ural Mountains, and, as in those countries, traversed by granites and porphyries. Sir R. Murchison remarks,‡ that the stanniferous (*tin-bearing*) gravels of Cornwall bear the same relation to the granite and killas as the auriferous deposits of the Urals to the erupted and schistose rocks of that chain.

5. Devonian Series or Old Red of Scotland.—The deposits of this system occupy an important place in the geology of Scotland. They have of late years attracted considerable attention from the interesting fossils they have yielded, and the admirable illustrations of the most important phenomena given by the late Mr. Hugh Miller in his delightful and instructive works.§ According to this charm-

* Murchison; Transact. Roy. Geol. Soc. Cornwall, vol. vi. p. 317, &c.

† Sedgwick; Quart. Journ. Geol. Soc. vol. viii. p. 1, &c.

‡ Jameson's Edinburgh Journal, 1847, vol. xliii. p. 40.

§ It is scarcely necessary to enumerate those of the well-known works of this gifted and lamented writer which more especially refer to his favourite and long-studied group of the "Old Red" strata. The *student* must necessarily have frequent recourse to the following for ing writer, the whole of the north-eastern part of Scotland, from the Pentland Frith to the mouth of the River Spey, consists of Devonian deposits resting on a central nucleus of crystalline rocks, viz. granite, gneiss, and micaceous schists. Similar strata are also found in insulated patches in various places of the interior of the country.

South of the Grampians, Devonian strata underlie the Carboniferous strata of Fifeshire; and a zone of these deposits skirts the southern flank of those mountains, from Stonehaven to the Frith of Clyde, and constitutes, with intrusive trap-rocks, the Sidlaw Hills and the Valley of Strathmore.

In a section * of the country from the foot of the Grampians, in Forfarshire, to the sea at Arbroath, a distance of about twenty miles, where the entire mass of strata is several thousand feet thick, a triple division of the Old Red Sandstone is very obvious; namely, 1st, and uppermost, yellowish sandstones, red and mottled shales, cornstone, and sandstone. 2. Conglomerates, often of vast thickness. 3. Tilestones and paving-stones, highly micaceous. The lowermost beds contain remains of grass-like or fucoidal plants in abundance, together with numerous small black patches (*Parka decipiens* of Fleming) resembling crushed blackberries, some of which have been regarded as the catkins of plants resembling rushes or sedges (Sparganium), whilst others have been thought to resemble more nearly the spawn of newts and other animals.†

The following is a general classification of the Devonian rocks of North Britain.‡

UPPER or Yellow Group.	Sandstones and shales. Reptiles (*Telerpeton Elginense* and foot-tracks); numerous fishes; some plant-remains. Pebbly grits and sandstone. Remains of fishes and plants

critical information on this interesting series and its fossils:—"The Old Red Sandstone, or New Walks in an Old Field;" "The Footprints of the Creator, or the Asterolepis of Stromness;" and "The Testimony of the Rocks."

* See Lyell's "Manual of Geology," 5th edit. p. 48; and Murchison's "Siluria," p. 248.

† See Quart. Journ. Geol. Soc. vol. viii. p. 106; and Lyell's "Manual of Geology," 5th edit. p. 421.

‡ Page's "Text Book," p. 124; Lyell's "Manual," p. 415, &c. See also Rep. Brit. Assoc. 1855, sect. p. 92.

MIDDLE or Red Group.	Sandstones and conglomerates, with shales and cornstones. (The typical "Old Red" of Cumberland, Fife, Perth, and Forfar.)
LOWER or Grey Group.	Micaceous sandy flagstones, sometimes bituminous; numerous fishes and plants (Caithness); flagstones and tilestones; fishes, crustaceans (*Pterygotus*), and plant-remains (Forfarshire); with sandstones and conglomerates.

The predominating colour of the great sandstones and conglomerates has probably been derived from the debris of the red granitic gneiss which forms chains of precipitous ridges in the north of Scotland. This rock contains hæmatitic iron-ore, diffused as a component of the stone throughout its entire mass; and this metal also occurs in insulated blocks of great richness, and in thin filiform veins.*

6. DEVONIAN ROCKS OF THE CONTINENT AND AMERICA.—On the Continent, Devonian strata are of wide extent.†

They have been well studied in Brittany, the Boulonnais, and Belgium. In Rhenish Prussia and the adjacent districts of Germany, they underlie the carboniferous series, and may be traced around, and dipping under, the coal-field of Westphalia. In the Rhenish Provinces, though the strata are often greatly contorted and broken, and even sometimes inverted or bent back,—the younger lying over the older beds,—yet a perfect and complete succession of groups of Devonian strata have been shown to exist in this region, chiefly by the labours of Sedgwick and Murchison,‡ d'Archiac and De Verneuil, Rœmer, and the brothers Sandberger.

* Miller's "Old Red Sandstone," p. 248.

† See Murchison and Nicol's Geol. Map of Europe; "Siluria," chapters 10, 13, 14, and 15; and Phillips' "Manual," p. 144.

‡ The important Memoir, "On the Distribution and Classification of the Older or Palæozoic Deposits of the North of Germany and Belgium, and their Comparison with Formations of the same age in the British Isles," by Sedgwick and Murchison, in the Geol. Trans. 2nd ser. vol. vi. p. 221, &c., followed by MM. d'Archiac and De Verneuil's "Descriptions of the Fossils of the Older Deposits in the Rhenish Provinces" (*ibid.* p. 303), was the groundwork for subsequent labours in this field. A full résumé of the subject, enriched with all the corrections and additions made since 1840, and noticing the views of others relative to some discussed points of classification, has been given to the public in Sir R. Murchison's late work on the history of the Palæozoic rocks, "Siluria;" and to this

The general order of the Rhenish Devonian series appears to be, 1st, (uppermost), Cypridina-schists, Clymenia-limestones, and Goniatite-schists; 2. the great Eifel-limestone and Calceola-schist; 3. Wissenbach-schists and the Coblentz-greywacke or Spirifer-sandstone.

In Russia, according to the researches of Sir R. I. Murchison and his colleagues,* the Devonian strata extend over an area of 150,000 square miles, a region more spacious than the British Isles; and yet throughout this vast superficies the series, though of less thickness, is even more distinctly marked by its typical fossils than in the disturbed districts of our own little Island: for the fossil fishes of Old Red schists of Scotland, and the fossil shells of Devonshire and the Eifel, are there found in the same deposits.

In North America, the Devonian deposits appear in a very prominent and characteristic form, surrounding each of the great coal-fields of the United States; and consist of a thick series of shales, sandstones, and flagstones, often rich with Devonian fossils, surmounted by red sandstone, conglomerate, and shales containing remains of some of the peculiar fishes which are so abundant also in the "old red sandstone" of England and Scotland. These Devonian rocks of North America are divided into the following 12 groups, in descending order, the Catskill, Chemung, and Portage groups, Genessee slate, Tully-limestone, Hamilton group, Marcellus-shales, Corniferous and Onondaga limestones, Schoharie and Cauda-galli grits, and the Oriskany sandstone. Devonian rocks occur also on the eastern side of the Rocky Mountains, along the great Mackenzie valley.†

Devonian fossils have been found also in South America (D'Orbigny),‡ the Falkland Islands (Darwin),§ Australia (Strezlecki),|| North and South Africa (Overweg¶ and Bain),** and China.†† In fact, the Devonian rocks are perhaps the most widely spread of all the palæozoic groups.

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standard authority the reader is referred for a full account of the Devonian rocks of Germany and Belgium, and a comparison of these with the Old Red series of Britain and other countries.

* "Geology of Russia in Europe and the Ural."

† Richardson and Isbister, Geol. Soc. Journ. vol. xi. p. 509.

‡ "Voyage dans l'Amerique Méridionale," p. 35.

§ Quart. Journ. Geol. Soc. vol. ii, p. 274.

|| "Physical Description of New South Wales and Van Diemen's Land: Appendix.

¶ Rep. Brit. Assoc. 1851, sect. p. 58.

** Trans. Geol. Soc. 2nd ser. vol. vii. pp. 182 and 224.

†† Bullet. l'Acad. *Belg. vol.* xiii. part 2, p. 415. Quart. Journ. Geol. *Soc. vol. ix. p. 353; and ibid.* vol. xii. p. 378.

7. ORGANIC REMAINS OF THE DEVONIAN.—The deposits comprised under the names of the "Old Red" and "Devonian" were formerly regarded as very sterile in organic remains, and classed among the so-called Transition rocks (vol. i. p. 37), in which it was supposed that traces of animal life first appeared. Modern researches, however, have shown that, though many of the strata are locally unproductive in fossils, yet others abound in the remains of corals, shells, crustaceans, and fishes. The marine fauna of this period is extremely rich, containing certain peculiar types, but, as a whole, forming a connecting link between the zoology of the Silurian series, which preceded it, and the Carboniferous, which followed.

Ichthyolites are abundant, and occasionally crustaceans, in some of the sandstones of Caithness, Cromarty, Forfar, Gamrie,* and other localities in Scotland, and in the Old Red Sandstone of Herefordshire; but only very slight traces of shells have been found. In the limestones and schists of Devonshire, on the contrary, shells, corals, crinoids, and trilobites are numerous.

Plants.—Of the vegetable kingdom, many traces are found in the Devonian series; as well as occasional intercalations of thin layers of coal and carbonaceous strata. As a whole, the Devonian flora is nearly related to that of the subsequent Carboniferous period.

The flagstones of Forfarshire abound with impressions of obscure plant-remains, and amongst these are found the blackberry-like fossils, already alluded to under the name of *Parka decipiens* (p. 787). These are groups of small, flattened hexagonal, carbonaceous bodies, occupying slight depressions in the stone; and, according to some observers,† are not always relics of seeds, but frequently are the remains of the spawn of molluscs and batrachians, and even possibly of crustaceans and fishes.

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* Prestwich, Geol. Trans. 2nd ser. vol. v. p. 139.

† *Fleming,* in Edinb. Journ. Nat. Science, 1831, vol. iii., and in *Murchison's "Siluria,"* p. 266; Mantell, Quart. Journ. Geol. Soc. vol. viii. *p. 10*[illegible] [illegible]nal, p. 421; Page, Text-book, p. 126.

The flagstones of Caithness and the Orkneys have afforded much more distinct evidences of the Devonian flora. According to Mr. Salter,* we have here the stems and roots of Conifers in abundance, with remains of Lycopodiaceous plants, not altogether dissimilar from some portions of the rich Devonian flora of the Thüringerwald, collected and described by Richter and Unger.†

In the "Yellow Sandstone" of Knocktopher, near Kilkenny, which is usually classed as Upper Devonian, ferns (*Cyclopteris Hibernica*), *Lepidodendron*, *Lepidophyllum*, and *Stigmaria* occur in profusion, associated with remains of *Holoptychius*, *Pterygotus*, and an Anodonta-like shell.‡ In North America also plant-remains are frequent in the Devonian strata, and Lepidodendron occurs low down in the series. Prof. Dawson § has recognised coniferous wood in the Devonian rocks of Gaspé, Canada

Zoophytes, &c.‖ — The Corals and Crinoids are numerous, and many of the genera are found also both in the Silurian and the Carboniferous rocks. *Alveolites*, *Favosites*, and

* Quart. Journ. Geol. Soc. vol. xiv. p. 72. See also Hugh Miller's "Testimony of the Rocks."

† Vienna Acad. Transact. vol. xi.

‡ Report Brit. Assoc. 1852, rep. sect. p. 43. See also Prof. Harkness's paper on the "Occurrence of Scalariform Tissue in the Devonian Rocks of Ireland." Edinb. New Phil. Journ. vol. iv. p. 65.

§ Proceed. Americ. Assoc. 10th meeting, p. 174

‖ For figures and descriptions of the fossil invertebrata of the Palæozoic rocks of Cornwall, Devon, and West Somerset, the student must consult Prof. Phillips's able "Report Pal. Foss.," &c., 1841; and the Memoirs by Sedgwick, Murchison, Lonsdale, and Austen, in the Geol. Transact. 2nd ser. vols. v. vi., &c. The Devonian Corals of Britain form the subject of a beautiful Monograph, by Milne Edwards and Haime, published by the Palæontographical Society, 1853. Agassiz's "Poiss. Foss." and Hugh Miller's "Old Red Sandstone" and other works illustrate the Devonian fishes. The Devonian fossils of Germany may be studied in the special Memoirs by D'Archiac and DeVerneuil, Richter and Unger, Rœmer, the Sandbergers, Geinitz, &c.; those of France are illustrated in many papers in the *Bulletin* and *Mémoires* of the Geological Society of France; and those of Russia have been described by D'Orbigny, and beautifully figured in the "Geol. Russia." Hall, Vanuxem, and others have well illustrated the Devonian fossils of North America. Several Devonian fossils are well figured in Lyell's "Manual," 5th edit., and in Murchison's "Siluria."

Cyathophyllum are common in the Mountain-limestone, the Devonian marbles, and the Upper Silurian of Dudley. The crinoideans comprise several genera, especially *Cyathocrinus* (p. 664) and *Hexacrinus*. *Pentremites* and *Echinosphærites* also occur. The bryozoa also are well represented in the Devonian rocks.

Mollusca.—The shells in some districts are very numerous, consisting of many genera of gasteropoda; as, *Euomphalus*, *Loxonema*, *Pleurotomaria*, *Murchisonia*, &c.; and acephala, as *Avicula*, *Cucullæa*, *Megalodon*, *Nucula*, &c.

But the most remarkable feature in the conchology of this epoch is the abundance of the ancient types of brachiopoda. In the British Devonian strata alone have been determined of *Athyris* 7 species, *Leptæna* 8, *Orthis* 12, *Rhynchonella* 19, and of *Spirifer* 27.

Of the higher order of molluscous animals, species of five genera are met with in Devonshire. The most common belong to *Orthoceras*, *Cyrtoceras*, *Goniatites*,* and *Clymenia*.† The Orthoceratites in the limestones of Devonshire often attain a large size. The shell is commonly changed into white calcareous spar, which in sections forms a beautiful contrast with the red hue of the surrounding rock.‡ Two species of *Nautilus* are found in Devon, and five species of the heteropodous *Bellerophon*.

8. Crustaceans of the Devonian Series.—In this formation the chief palæozoic type of Crustaceans, the Trilobite, is present in considerable numbers, though not rivalling the myriads that are imbedded in the Silurian rocks.

* Medals, p. 482. † Medals, p. 473.

‡ Polished slices of marble marked with sections of Orthoceratites are sold by the lapidaries of Torquay and Teignmouth. Medals, p. 474. The curious bodies, termed "Beekites," which are found in the New Red Conglomerate of Torquay, appear to have been rolled fossils of the Devonian limestone, which have been coated with chalcedony whilst in the conglomerate, and afterwards decomposed to a greater or less extent. See *Rep. Brit. Assoc.* 1856, sect. p. 74.

The *Phacops* is a common form; the spinose Homolonoti* are characteristic; and a peculiar trilobite, termed *Brontes flabellifer*, has hitherto been found only in the Devonian deposits.

Pterygotus.—A large species of an extinct genus of crustaceans, of a low type, occurs in the Devonian sandstone of Forfarshire, Herefordshire, &c.; and fragments of the carapace or shell have long been known to collectors as "*petrified Seraphims*," the name applied to these fossils by the quarrymen, from their fancied resemblance to the conventional figures of cherubs.† The first specimens which threw light on the nature of the original were discovered by Mr. Hugh Miller at Balruddery. The carapace of this animal forms a somewhat semicircular shield, and the long part of the body is protected by a succession of transverse plates, terminated by a caudal flap.‡ The claws resemble those of the common lobster. The crustaceous covering, or shell, is ornamented externally with circular and elliptical markings, which give it an imbricated, scaly, and somewhat feathered appearance: and it was the imprints of this surface that produced the enigmatical fossils to which the workmen ascribed a celestial origin! Some specimens in dicate a total length of eight feet.

Pterygotus occurs also in the uppermost of the Silurian deposits; and *Eurypterus*, an allied genus, occurs both in the Upper Silurian and in the Carboniferous rocks. Some of the small bivalvular entomostraca occur also in the Devonian rocks, such as the *Leperditia*;§ and a great group of schists

* Lyell's "Manual," p. 429. † Miller's "Old Red Sandstone."

‡ See Lyell's "Manual," 5th edit. p. 420, for a restored figure of this animal, by Prof. M'Coy; and the Quart. Journ. Geol. Soc. vol. xii. p. 28, for a figure of *Himantopterus* (a closely allied form), by Mr. Salter; see also Salter, *ibid.* vol. viii. p. 386, and Agassiz, "Foss. Vieux Grès Rouge," p. xix. By the kind permission of Sir R. Murchison, the Editor can also refer to p. 155 of the new edition of "Siluria," now in the press, for a restored figure of Pterygotus, by Mr. Salter.

§ *Annals Nat. Hist.* 2nd ser. vol. xviii. p. 89

in the upper part of the series is so full of the shells and casts of entomostraca, hitherto supposed to be *Cypridinæ*, that they are known as the "Cypridinen-schiefer." It is highly probable, however, that these entomostraca will prove to have little or no relation to the *Cypridina* of M. Milne Edwards, when carefully examined by crustaceologists.

9. Fishes and Reptiles of the Devonian Series.—M. Agassiz has determined no less than one hundred species of fossil fishes from the Devonian formation, in which, not very many years since, a few doubtful scales, discovered in Forfarshire by the late Dr. Fleming, were the only known vestiges of this class of vertebrated animals. In the British series there are upwards of ninety species, belonging to about thirty-five genera. Of these, the most characteristic

Lign. 184.—Cephalaspis Lyellii.

A flattened specimen showing the dorsal surface. (One-fourth the nat. size.) From the Devonian strata of Glammis, in Forfarshire.

are the *Cephalaspis*, *Pterichthys*, and *Coccosteus*, which form a group of extinct genera, that have only a few representatives in the uppermost portion of the Silurian formation below, and none in the Carboniferous rocks above; nor, except

stant and faint analogies with existing fishes, can these
kable organisms be brought within the pale of zoologi-
rangement. These ichthyolites agree in one general
cter, that of having relatively enormous osseous plates
utcheons covering the head and anterior portion of the

*halaspis.**—In the extraordinary genus of fishes, named *laspis* (*Head-buckler*) by M. Agassiz, the head is ed by a broad and thin buckler or shield of bone.† cales of the tail formed elevated bands, and the rays of ns were covered by the membrane which elsewhere sur- led them. From the large size of the plate forming over of the head, its lamellar structure, and crescent- form, terminating backwards in two horns or points, hed specimens were formerly supposed to belong to tri- s or some other crustaceans. The body is covered with s, and the shield is sometimes ornamented with radiated

LIGN. 185.—CEPHALASPIS LYELLII.

Lateral view, showing the produced dorsal lobe of the tail.

ings, as in *Cephalaspis ornatus* and *C. verrucosus*.‡ erous remains of these fishes have been found in the nian strata of Herefordshire, Scotland, and Russia. Mr.

ledals, p. 610. † Huxley; Geol. Proceed. January 6th, 1858.
‡ *Quart. Journ. Geol. Soc.* vol. xiv. p. 48.

Miller states, that in Scotland they are principally restricted to the group of cornstone and marls. Some species occur also in the uppermost Silurian strata.

*Pterichthys.**—The fishes of this genus are distinguished by two wing-like lateral appendages, which, like the spines of the common Bull-head (*Cottus gobio*), were weapons of defence. The head and anterior part of the body are covered with large angular tuberculated scutcheons. There are two eyes, which are placed in front of the lateral spines. Ten species occur in the British strata; mostly not exceeding eight or ten inches in length.

Coccosteus.†—In form, and in the arrangement of the bony scutcheons, the fishes of this genus have a resemblance to the Pterichthys. The plates are tuberculated; the tail is very long, covered with scales, and supports a fin. There are four or five species, varying in length from a few inches to two feet. Their remains are the most abundant of the ichthyolites of the Old Red rocks. Patches of detached scales and separate osseous plates are very frequent in the sandy cornstones and subcrystalline limestones. They are usually of a brilliant blue or purple colour, which, strongly contrasting with the dull red tint of the surrounding rock, renders them easy to be detected. This colour is supposed to be due to the presence of phosphate of iron.‡ In none of these fishes have any traces of vertebræ been discovered; it is therefore probable that the spinal column was cartilaginous, as in the Sturgeon.

Holoptychius.—My limits will only admit of a rapid notice of a few other Devonian ichthyolites. Among these, several species of the large ganoid fishes, named *Holoptychius*,§ from the peculiar character of the scales, are most

* *Wing-fish.* Medals of Creation, p. 612. Miller's "Old Red Sandstone."

† *Berry-boned:* from the plates being studded over with small tubercles. Medals of Creation, p. 614; Miller, *op. cit.*; and "Siluria," p. 252.

‡ "Silurian System," p. 588.

§ *Solid-wrinkled.* A splendid specimen of H. nobilissimus, twenty-strikingly conspicuous. This genus we have already noticed in the account of the carboniferous ichthyolites (p. 770).

Dendrodus.—This fish is allied to the Holoptychius, but the structure of the teeth, scales, and occipital plates is peculiar. The teeth are of a conical form, slightly curved, solid throughout, and finely striated longitudinally; and the calcigerous tubes are so disposed as to produce a dendritical or arborescent appearance in transverse sections; a character which is expressed by the name Dendrodus,* given to the fish by Prof. Owen.

Dipterus and *Diplopterus* are two nearly related genera of ganoid fishes, so named from their possessing two dorsal fins, which are placed opposite the anal and ventral fins. These fishes, together with the *Osteolepis*,† another common Devonian genus, have bony scales plated with enamel and finely punctated; and their jaws consisted of enamel without and bone within, and were beset with sharp-pointed teeth.

Glyptolepis, *Cheirolepis*, and *Cheiracanthus* ‡ are other characteristic fishes of this series of deposits. Of the placoid fishes (p. 352), species of the genera *Onchus* and *Ctenacanthus* have been discovered; but the placoideans are but feebly represented in the Devonian epoch, while the ganoid group is largely developed.

Reptiles.—The most ancient *reptilian* ichnolites or footprints are those discovered by Capt. Brickenden,§ in the Old Red Sandstone of Cummingston, near Elgin, which resemble the track of a Chelonian reptile. But still more in-

eight inches long, is figured in "Silurian System," pl. 2, and is now in the British Museum; "Petrif." p. 434.

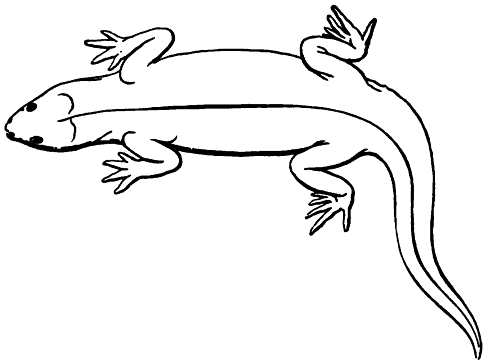
* *Tree-tooth.* Medals of Creation, p. 618, and Pl. VI. fig. 8.

† *Bony-scale.* Miller's "Old Red Sandstone," p. 80; and "Footprints of the Creator," p. 30.

‡ *Carved-scale*, *Hand-scale*, and *Hand-thorn.* Consult Hugh Miller's works above quoted; Agassiz's beautiful Monograph on the Fishes of the *Old Red Sandstone*; and Murchison's "Silurian System."

§ *Quart. Journ. Geol. Soc.* vol. viii. p. 97.

teresting evidence of the existence of oviparous quadrupeds in the Devonian period has been afforded by Mr. Duff's dis-



Lign. 186.—Telerpeton Elginense. From the Old Red Sandstone of Scotland.

Outline of the restored form of the original reptile: one-half the natural size.

covery of the skeleton of a small reptile in the same sandstone, near Elgin, that has yielded the footprints. This is the *Telerpeton Elginense* (Mantell),* a lacertian reptile with batrachian modifications. *Lign.* 186 exhibits, in outline, the probably newt-like shape of this interesting palæozoic reptile, at half the natural size.

10. The Silurian and Cambrian Rocks.—By reference to the synoptical arrangement of the formations (p. 205), it will be seen, that the great interval between the hypogene rocks (gneiss and mica-schist), and the Devonian series, as above described, is occupied by an immense thickness of

* Quart. Journ. Geol. Soc. vol. viii. p. 100; and "Medals of Creation," vol. ii. p. 720. This specimen was described, under the name of *Leptopleuron lacertinum*, by Prof. Owen, in the "Literary Gazette," contemporaneously with Dr. Mantell's communication on the subject to the Geological Society.

ks, limestones, sandstones, and argillaceous strata. eposits were formerly grouped with some of the De- rocks, under the name of *Transition-rocks;* a desig- applied by the celebrated Werner upon the supposi- t they were formed when the world was in a state of n from a chaotic to a habitable condition: they so termed *Grauwacké*,* from the hardened gritty r of many of the strata, but the whole series is now into two natural groups. The uppermost has been ed the UPPER SILURIAN,† by Sir R. I. Murchison, ndefatigable researches have determined the true , relation, and character of these deposits; the lower eing his LOWER SILURIAN and BOTTOM ROCKS: by the Rev. Professor Sedgwick, whose successful in this difficult field of geological investigation have d clear and intelligible many phenomena which were ly involved in doubt and obscurity, the upper group d SILURIAN, and the lower one CAMBRIAN.‡

e here the inconvenience of a double set of terms, which be- ched to these important groups of lower palæozoic rocks in this en Sir R. Murchison was reducing to order and classifying his " rocks § of Shropshire, which were found to repose on the

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1 the German *grau*, grey, and *wacké*, a name employed by the ainers to denote some hardened grits and basaltic rocks.

ian—a term derived from *Silures*, the ancient Britons who in- ose parts of our Island where these strata are most distinctly .

brian—from the old name of Wales. In the Map, p. 474, the nd Cambrian rocks are denoted by the same number (8) and

he classic work, "The Silurian System, founded on Geological s in the Counties of Salop, Hereford, Radnor, Montgomery, en, Brecon, Pembroke, Monmouth, Gloucester, Worcester, and with Descriptions of the Coal-fields and overlying Formations;" ck Impey Murchison, F. R. S., &c., 4to, with a Map and nu- lustrations. London, 1839. The publication of this splendid ed an era in British *geology*; it is a noble monument of pa-unfossiliferous greywacke of the Longmynd, Prof. Sedgwick was elucidating the contorted, dislocated, and slaty rock-masses of North Wales,* which he termed "Cambrian," and which were then believed to be older than any of the "Silurian" strata. The North Welsh fossils, however, were not described; nor were the exact relations of the strata of the two districts made out. Subsequently, on the one hand, it was determined, chiefly by the labours of the Geological Survey, that the fossiliferous strata of Cambria, or North and South Wales, are replications, expansions, and curvatures of the Shropshire or Silurian strata (the Cambrian equivalents being, however, for the most part, in a much more crystalline condition, and much more intersected and intercalated with igneous rocks); the fossiliferous schists both of Cambria and Siluria equally reposing on unfossiliferous greywacke—that of the Longmynd on the east, and that of Anglesea, Harlech, and St. David's, on the west. To these latter or "Bottom Rocks" the Geological Surveyors thought fit to limit the term "Cambrian;" applying the names "Lower and Upper Silurian" to the great overlying fossiliferous groups. This nomenclature became generally adopted in Europe and America, as the equivalent formations were detected and classified. At a later period Prof. Sedgwick and Prof. M'Coy, having diligently worked out the fossils of North Wales, and reëxamined much of the ground, endeavoured to define the exact limit of the lower and upper portions of the series, retaining for the former Prof. Sedgwick's early term "Cambrian," and applying that of "Silurian" to the upper group only. The Geological Surveyors also, about the same time, carefully directed their attention to the same points of research, corroborating and extending the known facts, but without essentially altering the received nomenclature.

In 1854, Sir R. Murchison published a comprehensive and popular review of the Palæozoic Rocks and Fossils, in his valuable and widely

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tient, laborious, and successful scientific research, pursued through a long series of years, regardless of toil, time, or expense. The results of the labours of its highly gifted author were alike novel and important: rocks, which, under the names of transition and greywacke, were previously considered without the pale of scientific arrangement, were for the first time reduced to a regular system, and their zoological characters as well defined as those which mark the newer secondary formations. This is truly a national work: the description of the British coal-fields is as important in an economical as in a scientific point of view.

* See the several valuable Memoirs by Prof. Sedgwick, in the publications of the Geological Society, on the Palæozoic Rocks of Wales and the North of England.

irculated "Siluria," adopting the required modifications and corrections the account of fossils and rocks (with careful revision of the map), nd stating at large his views of the classification and nomenclature of e Silurian and Cambrian strata.

Lastly, Prof. Sedgwick, in 1855, explained, in the magnificent work by imself and Prof. M'Coy, entitled "A Synopsis of the Classification of e British Palæozoic Rocks; with a Systematic Description of the ritish Palæozoic Fossils in the Geological Museum of the University of ambridge" (4to, Cambridge, with numerous plates), the grounds on hich he applied the term "Cambrian" to the lower and larger portion f the series in question, and his reasons for regarding this group (the ower Silurian and Bottom Rocks, of Murchison) as being distinctly ifferent in physical and zoological characters from the overlying group he Upper Silurian, of Murchison).

Guided by the light thus thrown, during several years, on these Lower 'alæozoic rocks and fossils by Sedgwick, Murchison, De la Beche, Phillips, Sharpe, M'Coy, Salter, Forbes, Ramsay, Jukes, Aveline, Selwyn, nd many other good observers, geologists have, with but few exceptions, dopted Murchison's general classification of the Lower Palæozoic trata of Great Britain.* (See Table, p. 801, 802, in which the greater nd lesser groups of strata are carefully indicated, and the chief of their haracteristic fossils enumerated.)

In this elementary work, avoiding all technical argumentation, the atest classification of these ancient and most interesting rocks is placed before the reader in the accompanying Table, which shows both plans of nomenclature before alluded to.

The Editor gratefully acknowledges Sir Roderick Murchison's kindness, in allowing him free access to the proof-sheets of the 2nd edition of "Siluria," now in the press, and thereby enabling him to make the classification more complete than it could otherwise have possibly been, even with the aid of the papers and memoirs published since the 1st edition of "Siluria." The especial points of novelty are—the better understanding of the Uppermost Ludlow Rocks (Tilestones) and their fossils,—the clearer determination of the Middle Silurian Strata,—the identification of the Bala and the Caradoc Rocks,—the improved lists of

* The reader is referred to the highly important works above mentioned, and to numerous memoirs and papers in the Proceedings and Journal of the Geological Society, for the particulars of the progress of research in the Silurian and Cambrian rocks, and for the arguments used with respect to the adoption of the two several plans of nomenclature See also the Philosophical Magazine for 1854.

fossils,—and particularly the recent discovery of the primary age of the red conglomerates of Sutherland and Ross.

The whole of these strata are of marine origin; and the limestones and shales often swarm with trilobites, crinoids, corals, brachiopods, and other fossils, with which our late investigations have made us familiar. The subdivisions introduced are locally important; but a general analogy prevails in the organic remains throughout the entire system, and there does not appear to be any essential variation in the forms or conditions of organic life, as deducible from the fossils, from the commencement to the termination of the series; and, though each principal division may be distinguished by its peculiar fossils, yet the Upper and Lower Silurian (or Cambrian) rocks are bound together by many species common to both, and form but one great natural system.

The Upper Silurian is estimated to have a thickness of about 5000 feet; the Middle, 2000 feet; the Caradoc and Llandeilo groups, together, attain nearly 19,000 feet; and the Longmynd rocks, upwards of 25,000 feet. This is in strong contrast to the slight vertical development of the Silurian rocks of Norway, where the whole series, complete in all its members, attains no more than 2000 feet thickness.*

11. SILURIAN AND CAMBRIAN ROCKS OF THE BRITISH ISLES.—Both the lithological and the zoological characters of this great series, and even of its principal subdivisions, are found to prevail not only in England, over the continent of Europe, and beyond the Ural to the Himalayas, but also in North America, where the Silurian and Cambrian rocks are largely developed, forming great tracts in the United States, Canada, and the Arctic Regions.

In Cornwall, Lower Silurian or Cambrian rocks appear in two of the southern headlands, emerging from beneath the predominant strata of the district, the Devonian, and containing characteristic fossils.† But the chief development

* Quart. Journ. Geol. Soc. vol. xiv. p. 43. † *Ibid.* vol. viii. p. 2.

of the series in Britain is in the Border-counties and Wales.*

In Cumberland and Westmoreland, the Lower Palæozoic rocks are also extensively exposed, presenting an enormous aggregate thickness,—upwards of 20,000 feet. These old *Cumbrian* strata have been specially studied by Prof. Sedgwick.†

The Lake-district, so well known to the tourist, may be described as a circular cluster (or *massif*) of mountains, the central portion consisting of serrated peaks of schistose rocks, thrown into their present position by granite and other igneous masses which constitute the true geological centres of the mountain-groups. The outskirts of this region are chiefly formed by Carboniferous deposits; a zone of Mountain-limestone appearing on the east, north, and south; and the western side is bounded by the Irish Sea.

Within the calcareous zone, are several extensive masses of granite, syenite, and porphyry, but the greater part of the region is occupied by stratified deposits of a slaty texture, which, according to Prof. Sedgwick, may be subdivided into the four following formations, commencing with the uppermost:—1. Greywacke-slate, often more or less calca-

* The student must necessarily consult the maps and sections published by the Geological Survey; and it will be of advantage to have at hand Knipe's Geological Map of the British Isles, which presents a *coup d'œil* of the geographical distribution of these formations over the British Islands. Their extension over Europe into Western Asia may be studied in Murchison and Nicol's Geological Map of Europe (K. Johnston). Hall's Geological Map of the United States, that by Prof. H. Rogers, in K. Johnston's "Physical Atlas," and Sir W. Logan's Geological Maps of Canada, in Quart. Journ. Geol. Soc. vol. viii. pl. 6, and in his "Esquisse Géologique du Canada," 1855, with Isbister's Geological Sketch-Map of the Arctic Regions, Geol. Soc. Journ. vol. xi. pl. 14, and that constructed by Haughton and Macclintock, Journ. Roy. Dublin Soc. February, 1857, illustrate the Palæozoic deposits of North America.

† His Memoir, in the Geol. Soc. Journ. vol. viii. p. 35, contains some of his latest researches in these rocks, with illustrative sections and full references to former Memoirs. See also *ibid.* pp. 136—142; and Geol. Trans. 2nd ser. vol. iv. p. 45, &c.

reous, and having subordinate beds passing into impure limestone, full of organic remains. 2. Green quartzose roofing-slate, associated, in every variety of complication, with felspathic rocks of porphyritic structure. 3. Black glossy clay-slate, sometimes passing into greywacke. 4. Various crystalline slates, resting immediately on the granite of Skiddaw Forest, and forming the base of the whole stratified series.

These rocks have also been classified by the same eminent geologist according to the following local groups:—1. Flags and grits of Kirkby Moor; 2. Slate and grit-stone; 3. Ireleth slates; 4. Coniston grit, flagstone, and limestone; 5. Slates and porphyry; 6. Skiddaw slates. Nos. 1, 2, and 3 are the equivalents of the Ludlow and Wenlock groups; the others represent the great lower groups of Caradoc, Llandeilo, &c.

In South Scotland the Silurian rocks and fossils* have been worked out by Sedgwick, Murchison, J. Nicol, J. C. Moore, Harkness, M'Coy, Salter, and others; especially in Ayrshire, Wigtonshire, Dumfries, and other neighbouring districts.

In the North-west of Scotland the late researches of Mr. Peach and others have enabled Sir Roderick Murchison to coördinate the old quartzites, schists, silicious limestones and sandstones of Durness and Loch Eribol with the Lower Silurian rocks of Wales; and to refer the great conglomerates of Western Sutherlandshire and Ross to the Longmynd or Bottom Rocks; correcting the long-held notion of their being of the same series as the Old Red conglomerates of Caithness and the Eastern coast. These primæval deposits rise on the northern shores of Lochness in an immense mass of conglomerate, based on a small-grained red granite, to a height of three thousand feet above the sea-level; and on the north-western coast of Ross-shire, form three immense insulated hills (*Suil-veinn*, *Coul-beg*, and *Coul-*

* See Proceed. Geol. Soc. vol. iii. pp. 277 and 553; Quart. Geol. Jo[illegible] p. 195; vol. vi. pp. 53 and 206; vol. vii. pp. 46 and 15 and 238; also "Siluria," p. 149, &c.

more *), of as great an altitude, that rest unconformably on a base of gneiss.† (See "Siluria," 2nd edit. p. 195, &c.)

Silurian rocks occupy large areas in Ireland,‡ and have been described by Weaver, Griffith, Portlock, and others. The complete view, however, given of these strata in Murchison's "Siluria" must be referred to by the student. The coast of Ireland opposite to that of Wales and Cumberland is formed of Silurian and Cambrian strata, which spread also over Wexford and part of Waterford and Wicklow; an enormous intrusion of igneous rocks rising up in Carlow, and reaching to the shore of Dublin Bay, at Kingstown. From Drogheda Bay to Belfast Lough similar deposits appear, covering a great portion of Armagh, Monaghan, and Louth; the whole sinking westward beneath the vast region of Carboniferous deposits which occupy more than one-half the entire area of Ireland.

12. THE LONGMYND OR BOTTOM ROCKS.—In Shropshire there is a group of old stratified rocks, unconformable to the overlying strata of the Llandeilo group, having evidently been thrown into highly inclined positions before the deposition of the latter. These rocks form the *Longmynd* and contiguous ranges of hills, comprising Ratlinghope, Linley, Pontesford, &c., and vary in height from 1000 to 1600 feet. The strata consist of hard sandstone, grit, and schist, raised up in mural masses, the beds being either vertical, or in very highly inclined positions.§

On the western flank of the Longmynd the schists dip conformably under the Lowest Silurian of the *Stiper Stones*,

* See a beautiful sketch of these Mountains, in "Siluria." These insular rocky mountains are cited by Macculloch ("Western Isles," vol. ii. p. 90) and by Lyell ("Manual of Geology," p. 67) as instructive examples of the vast amount of denudation which has taken place in many countries.

† Hugh Miller's "Old Red Sandstone." 1841, p. 23.

‡ See Griffith's Geological Map of Ireland

§ *"Silurian System,"* chap. xxi. "Siluria;" and Quart. Journ. Geol. *Soc. vol. xiii. p. 200.*

as represented by Sir R. Murchison ("Sil. Syst." pl. 32); but on the south and east they are unconformably overlaid by the Upper Llandovery beds and the Wenlock shale.

According to the observations of the Government Geological Surveyors, the greywacke of the Longmynd is from 30,000 to 40,000 feet thick; and, though composed of nearly unaltered * beds of sediment, it has yielded but very few traces of organic remains. These few valuable relics have been discovered in the upper portion of the Longmynd rocks by the acuteness and persevering energy of Mr. J. W. Salter,† F. G. S., Palæontologist of the Geological Survey; and consist of two portions of a Trilobite, numerous Annelide-burrows and Worm-tracks, Wave-marks, the casts of Sun-cracks, and even of Rain-prints; distinctly recording the daily working of wave, wind, and cloud, and the existence of some, at least, of the inhabitants of a shore-margined sea in incalculably ancient periods, long anterior to the immeasurable ages the history of which we have but faintly sketched in the foregoing chapters of this book.

Ancient deposits equivalent to the *Longmynd*, *Lowest Cambrian*, or *Bottom Rocks*, have been recognised at St. David's in South Wales, between Barmouth and Harlech, and around Llanberris and Bangor in North Wales; but annelide-marks,‡ discovered in the Bangor schists by Mr. Salter, are the only evidences of organic life as yet noticed.

* The slaty rocks of Wales, in which fossils often abound, are far more altered than these strata of the Longmynd, which are only in part highly mineralized, and chiefly where they have been intruded upon by trap-rocks, and impregnated with copper-veins, bitumen, and other minerals. —*Sil. Syst.* p. 261.

† See Mr. Salter's descriptions and figures of these primæval vestiges, in the Journ. Geol. Soc. vol. xii. p. 246; and *ibid.* vol. xiii. p. 199.

‡ These consist of worm-tubes crossing each other, and so giving rise to a fucoidal marking, which was described by Mr. Salter (Geol. Soc. Journ. vol. xii. p. 246) as being probably a *Chondrites*, but has since been proved by this accomplished geologist to be formed of worm-tracks, as indeed (Mr. Salter thinks) all, or nearly all, the so-called fucoids of the palæozoic rocks may turn out to be.

In Ireland, the grauwacke of Bray Head is of the same age, and yields annelide-burrows and the enigmatical fossil known as *Oldhamia*,* of which two species have been found.

The discovery that the great conglomerates resting on the gneiss of the North-west Highlands belong to the Longmynd age, already alluded to (p. 806), enlarges our knowledge of the complete succession of the Lowest Palæozoic rocks, and brings the British series into close accordance with that of Scandinavia on the one hand, and that of Canada on the other.

The discovery, however, of organic fossils in some of these Bottom-rocks destroys the propriety of the term "Azoic" † that has been so long applied to them; and (like the unexpected appearance of mammalian teeth in the Triassic bone-bed of Stuttgart, of *Dromatherium* in the Chatham strata of the United States, of *Dendrerpeton* and *Pupa* in the coal of Nova Scotia, and of *Telerpeton* in the Old Red Sandstone) warns us to be cautious in accepting negative evidence in support of geological hypotheses.‡

13. Silurian strata of Staffordshire.—Among the British Silurian districts, the country around Dudley, Walsall, and other parts of Staffordshire demands especial notice from the interesting circumstances under which these palæozoic rocks occur; being isolated, as it were, from the great regions of the formation, and thrown up amidst the newer deposits, like islands in the Triassic and Carboniferous areas: and the facility of access to these localities, by the railroads from the metropolis, renders them peculiarly valuable to the geological student.

* Forbes, Journ. Geol. Soc. Dublin, vol. iv. p. 20. Whether this fossil represents a Bryozoan, a Zoophyte, or a sea-weed, is as yet undetermined.

† "Without life."

‡ See Lyell's "Manual of Geology," 5th edit. p. 462.

At the distance of about 120 miles from London, an insulated mass of Silurian rocks is protruded through the once-overlying Carboniferous and Triassic strata at Walsall, and forms a ridge of hills on the eastern borders of the great Staffordshire coal-field; while near Dudley, a few miles to the south-west, another range of Silurian hills, produced by a similar upheaval, appears in the midst of the same Carboniferous basin; and near these hills is a mass of volcanic rocks, called Rowley Hill.*

The town of Dudley is situated partly on the coal-field, and partly on the group of Silurian rocks which constitutes a prominent feature in the physical characters of the landscape. These Silurian deposits rise into an elevated chain of hills, which extends four or five miles diagonally across the coal-basin, in a line from Dudley to Wolverhampton; the latter town standing on Triassic strata near the western margin of the coal-field.† The aspect of the surface of the country denotes the nature of the sub-soil, for the Triassic districts are generally covered with verdure; while those of the coal, from the extensive mining operations everywhere in progress, present for the most part a character of sterility and desolation.

In the Dudley Silurian range, three hills are strikingly conspicuous, namely Sedgley, which is composed of the Upper Ludlow rock and Aymestry limestone,—and the Wren's Nest and the Castle Hill, consisting of Wenlock shale and limestone; these hills, with their connecting valleys, form a verdant tract in the midst of the surrounding coal-measures.

The most remarkable eminence of this group is that called the *Wren's Nest*, which is a steep headland, covered on the top with stunted wood, and presenting the appearance of a truncated dome; its summit is deeply excavated, whence the common ironical name. This hill, as shown in *Lign.* 187, consists of arched strata of Wenlock shale and limestone. The limestone teems with the characteristic fossils of this division of the Silurian series (see Table, p. 801). Castle Hill and Hurst Hill are similar and parallel upheaved masses.

The truncated appearance of the summit of Wren's Nest has evidently originated from the denudation of the upper part of the dome of which it once consisted; the strata having been originally protruded in an arched position, as in Kettle Hill (see the section, *Lign.* 187); and we have in these Silurian limestones and shales a corresponding struc-

* See the Map accompanying the "Silurian System," or that in "Siluria."

† See p. 688, for an account of a fossil forest in a colliery near Wolverhampton.

ure with that observable in the mountain-limestone of Crich Hil. in Derbyshire, of which we have already spoken (p. 699).

1. Wenlock shale. 2. Wenlock or Dudley limestone. 3. Coal-measures.

Lign. 187.—Section of Silurian and Carboniferous Strata, near Dudley.

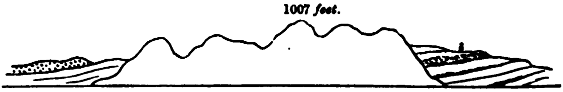
14. The Clent Hills.—In the above-described section, the upheaved and contorted sedimentary deposits are alone displayed; the deep-seated volcanic mass, by which they were elevated and thrown into their present position, being concealed from view. But in several places in the surrounding district, the intrusive igneous rocks appear above the surface, in sharply-defined ridges; as in the Rowley Hill, near Dudley, and those of the Clent, Romsley, and Lickey; and the more distant ranges of Abberley and the Malverns in Worcestershire.

About two miles to the south of the Dudley coal-basin, and stretching in a parallel direction with the Silurian range previously described, is another chain of hills, about six miles in length, and varying in height from 800 to 1000 feet, called the Clent Hills.* This elevated district is formed by a protrusion of felspathic trap-rocks through Permian strata, consisting of conglomerate and sandstone, with cornstone and traces of coal, as shown in *Lign.* 188.† This basaltic eruption must have taken place after the Carboniferous strata were deposited, and long

* Within the precincts of the Clent Hills are Hagly, the seat of Lord Lyttleton, which the muse of Thomson has rendered classic ground, and the equally celebrated Leasowes of Shenstone.

† The trap or volcanic rock of the Clent, Lickey, and Abberley Hills is chiefly composed of brownish-red compact felspar, occasionally porphyritic, and sometimes passing into a fine concretionary rock.—*Sil. Syst.* p. 496; and *Records Geol. Survey*, vol. i. part 2, p. 240.

antecedent to the Triassic period, the strata of which age have been quietly deposited on the southern flank of the Clent Hills, as seen in *Lign.* 188.



LIGN. 188.—SECTION OF THE CLENT HILLS.
(Sil. Syst. pl. 29, part of fig. 10.)

The following description by Mr. Hugh Miller is too characteristic to be omitted :—

"The New Red Sandstone, out of which the Clent Hills rise, forms a rich, slightly undulating country, reticulated by many a green lane and luxuriant hedge-row; the hills themselves are deeply scooped by hollow dells, furrowed by shaggy ravines, and roughened by confluent eminences; and on the south-western slopes of one of the finest and most variegated of the range, half on the comparatively level red sandstone, half on the steep-sided billowy trap, lie the grounds of Hagly. Let the Edinburgh reader imagine such a trap-hill as that which rises on the north-east between Arthur's Seat and the sea tripled or quadrupled in its extent of base, hollowed by dells and ravines of considerable depth, covered by a soil capable of sustaining the noblest trees, mottled over with votive urns, temples, and obelisks, and traversed by many a winding walk, skilfully designed to lay open every beauty of the place, and he will have no very inadequate idea of the British Tempe sung by Thomson. We find its loveliness compounded of two simple geological elements,—that abrupt and variegated picturesqueness for which the trap-rocks are so famous, and which may be seen so strikingly illustrated in the neighbourhood of Edinburgh, and that soft-lined and level beauty—an exquisite component in landscape when it does not stand too much alone—so characteristic, in many localities, of the Lower New Red Sandstone formation. . . . . From the hill-top,* the far Welsh mountains, though lessened in the distance to a mere azure ripple, that but barely roughened

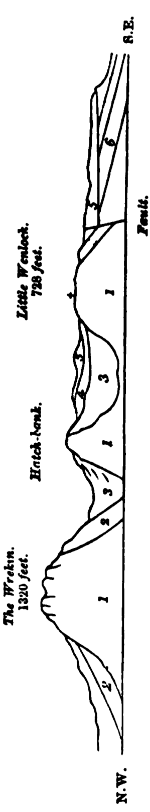
* The eminence so glowingly described by Thomson :—
"Meanwhile you gain the top from whose fair brow
The bursting prospect spreads immense around," &c.

the line of the horizon, were as distinctly defined in the clear atmosphere as the green luxuriant leafage in the foreground, which harmonized so exquisitely with their blue. The line extended from far beyond the Shropshire Wrekin, on the right, to far beyond the Worcestershire Malverns, on the left. . . . . . . In the foreground we have the undulating trap. . . . . . Next succeeds an extended plain of the richly-cultivated New Red Sandstone, which, occupying fully two-thirds of the entire landscape, forms the whole of what a painter would term its middle ground, and a little more. There rises over this plain, in the distance, a ridgy acclivity, much fretted by inequalities, composed of an Old Red Sandstone formation coherent enough to have resisted those denuding agencies by which the softer deposits have been worn down; while the distant sea of blue hills, that seem as if toppling over it, has been scooped out of the Silurian formations, Upper and Lower, and demonstrates in its commanding altitude and bold wavy outline the still greater solidity of the materials which compose it."*

15. The Wrekin.—The Dudley coal-field is remarkable for the beds of volcanic grit intercalated between the upper strata of the Coal-measures and the Permian deposits; and which Sir R. Murchison is of opinion were formed from the detritus of submarine volcanos, which were in activity towards the close of the Carboniferous epoch.† The solid intrusive trap-rocks are of a later date, and appear in various detached points near Dudley. The largest mass constitutes Rowley Hill, a ridge two miles and a half long, and one mile wide, extending from Rowley Regis to the southern suburbs of Dudley. This trap-rock, known locally as the *Rowley-rag*, is a hard, fine-grained, crystalline green-stone, or basalt,‡ being an admixture of grains of hornblende with small crystals of felspar and quartz. This mineral appears in a slender columnar form in Pearl Quarry, near Timmin's Hill, at Rowley.

* "First Impressions of England and its People," by Hugh Miller; London, 1847, p. 111, &c. † "Silurian System," p. 468.

‡ This trap-rock supplied the materials for the important experiments, by Gregory Watt and Sir James Hall, on the fusion and cooling of rocks; and has of late been employed by Messrs. Chance, at Oldbury, near Birmingham, in the manufacture of molten indestructible architectural materials.



1, 1, 1. Trap-rock. 2, 2. Quartz-rock: Lower Silurian strata altered from contact with the trap. 3. Caradoc sandstone. 4. Carboniferous limestone. 5, 5. Coal-measures. 6. Wenlock shale.

LIGN. 189.—SECTION THROUGH THE WREKIN TO THE VALLEY OF THE SEVERN. (*Sil. System*, p. 225, *pl.* 29, *part of fig.* 17.)

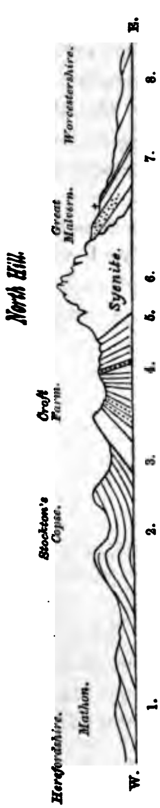
But one of the most i examples of erupted tr part of England is that formed the hill called tl near Wellington in Shr the north-west flank of field of Coalbrook Dale; must have taken place accumulation of the Silu as the latter were eviden into inclined positions Carboniferous were depos a subsequent period, and this consolidation, the coa were in their turn pierc versed by other intruded igneous rock, differing matter, but erupted in lines of fissure, parallel the Wrekin.

The *Wrekin* is an elliptica a mile and a quarter long, its mit being 1320 feet above the sea. It is composed of ig having on its flanks various the Silurian and Carboniferous shown in the section, *Lign.* 18 mentary deposits within the inf erupted volcanic rocks have un siderable alteration; the sandstone being changed into gran rock, much of which is pure white quartz, with particles of felspar, and sometimes much resembling submarine volcanic in some places this rock becomes a brecciated aggregate.

The igneous rock-masses are various modifications of pir

* The erupted trap forming Barrow Hill (see p. 700) is structive example of this phenomenon.

red syenite, consisting of compact felspar with white quartz, and disseminated chlorite: in some parts the mass is made up of felspar with green-earth and veins of carbonate of lime. To the south-east of the Wrekin, bosses of a basaltic green-stone, of irregular shape, appear around the village of Little Wenlock (*Lign.* 189).



1. Old Red Sandstone. 2. Ludlow rocks. 3. Wenlock limestone. 4. May Hill sandstone and grit, overturned. 5. Old Silurian schistose rocks. 6. Syenite. 7. Permian Breccia. 8. New Red Sandstone.

LIGN. 190.—SECTION THROUGH THE MALVERN HILLS. (*Sil. Syst. pl.* 36, *fig.* 7.)

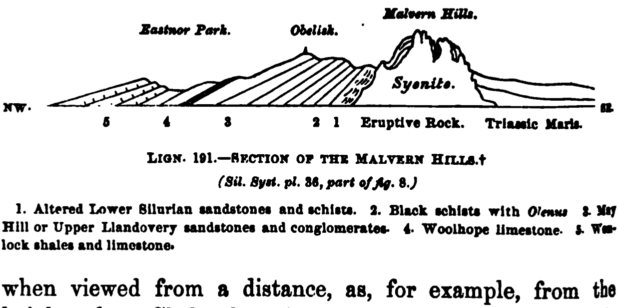
The invaluable work to which I am indebted for most of the interesting facts thus briefly noticed should be referred to for full details of the geological structure and relations of the deposits under review. The eminent author considers that this district of Shropshire affords unequivocal evidence of the alternate activity and repose of volcanic action, during very long periods in the palæozoic ages; and that the following sequence of geological events is clearly established:—1. that volcanic grits were formed during the deposition of the Lower Silurian strata;—2. the Upper Silurian rocks and Devonian sandstone were accumulated tranquilly, without a trace of contemporaneous eruptions; — 3. after their consolidation, the last-mentioned deposits were dismembered, and set upon their edges by vast outbursts of intrusive trap;—4. the Carboniferous beds were deposited after the older strata were upheaved; and 5. that subsequent dislocations, including some of the most violent with which we are acquainted, took place after the deposition of the Coal-measures and Permian sandstone.*

16. THE MALVERN HILLS, &c.—In Worcestershire, the different members of the Silurian system are well developed, and, though occupying a narrower zone than in Shropshire, constitute a continuous band for a distance of between twenty and thirty

* "Silurian System," p. 235. This subject is also treated of in "Siluria."

miles; viz. from the northern end of the Abberley Hills, to the southern extremity of the Malverns; "and, though the strata are dislocated, and even through a course of four miles entirely *reversed*, yet they maintain a prevalent inclination to the west, and dip beneath the Old Red Sandstone of Herefordshire. Emerging through the Silurian deposits, and forming a buttress on their eastern flank, are certain igneous rocks, which, in the Abberley Hills, protrude only at intervals through the dislocated strata, but in the Malverns constitute a narrow ridge of syenite, rising to some height above the Silurian deposits;" * as represented in *Ligns.* 190, 191.

The Malvern Hills are situated in the south-western part of Worcestershire, and consist of an uninterrupted chain about nine miles long, and two wide, the highest summits attaining an altitude of nearly 1500 feet. This outline,



LIGN. 191.—SECTION OF THE MALVERN HILLS.†
(Sil. Syst. pl. 36, part of fig. 8.)

1. Altered Lower Silurian sandstones and schists. 2. Black schists with *Olenus* 3. May Hill or Upper Llandovery sandstones and conglomerates. 4. Woolhope limestone. 5. Wenlock shales and limestone.

when viewed from a distance, as, for example, from the heights above Cheltenham, is very striking, and characteristic of their geological structure. The three highest points are the Herefordshire and Worcestershire beacons, and North

* "Silurian System," p. 410; "Siluria," p. 92; and Phillips' Memoir on the Malvern and Abberly Hills, in the Mem. Geol. Survey, vol. ii. part 1; also his "Manual of Geology," p. 513; and Notices Roy. Instit. Great Brit. 1857, part 7, p. 386.

† See also "Siluria," p. 94; *ibid.*, 2nd edit. p. 192, &c.

Hill (*Lign.* 190), formed by the protruded syenitic rocks, which form the nucleus of this mountain-range.*

In passing from Herefordshire to Worcestershire, in a line from west to east (see *Lign.* 190), the Devonian or Old Red strata first appear, and are succeeded by the Upper Silurian, namely, the Ludlow and Wenlock deposits; next follow beds of May Hill sandstone, and we then arrive at the protruded peaks of igneous rock, and descend over the Permian Conglomerate and Triassic strata to the plains of Worcestershire. The relative position of the strata and the erupted rocks is shown in the anexed diagrams (*Ligns.* 189, 190, and 191). The entire succession of the Silurian series, between the Syenite of the Malverns and the Old Red Sandstone, is well exposed in a transverse section from Midsummer Hill to Ledbury.

There is one feature in the geology of the Malvern Hills that demands particular notice. The Silurian strata in immediate contact with the syenite are sometimes partly bent back, or inverted, as shown in the section, *Lign.* 190, in which the Wenlock limestone (3.) is seen at a distance from the syenite and unaffected, whilst the May Hill sandstone and grit (4.) are overturned and dip in an opposite direction.

In the Abberley Hills, the same phenomenon appears in a more striking point of view; and through a range of four or five miles, the Devonian, Ludlow, and Wenlock strata are completely inverted, the newer formations being overlaid by the older; "so symmetrical, indeed, is the reversal in this part of the range, that any geologist who had not previously made himself acquainted with the true order of superposition would naturally conceive the Wenlock limestone to be younger than the Ludlow rock, and the Ludlow rock than the Old Red Sandstone." †

The Lickey Hills, which are situated about three miles from the southern extremity of the Dudley coal-field, consist of a narrow ridge of quartz-rocks, about three miles in length and four or five hundred feet high, and are referred by Sir R. I. Murchison to the Upper Llandovery

* A very interesting Memoir on the mineralogy of the Malvern Hills, by Mr. Leonard Horner, was published in the Geol. Trans. 1st ser. vol. i p. 281.

† "Silurian System," p. 421.

sandstone; the quartz-rock of the Lickey gradually passing into a fossiliferous sandstone containing the characteristic organic remains of the Pentamerus-zone.* A mass of trap, being the prolongation of that of the Clent and Abberley Hills, forms the nucleus of the ridge, and appears in the point called Lickey Beacon, on the northern end of the Bromsgrove Lickey Hills, which consist, in great part, of Permian and Triassic strata.†

The Valley of Woolhope, which lies to the west of the southern extremity of the Malverns, about three or four miles from Hereford, is a remarkable instance of what geologists term a "valley of elevation;" being a dome-shaped protrusion of Silurian rocks through the Devonian deposits, of which the surrounding region consists. This elevated mass of strata is of an oval form, being six miles long, and four wide. Within this area, the Upper Silurian strata are thrown up into concentric and conformable masses, each dipping outwards from a common centre, and the whole passing beneath the Old Red Sandstone. The central nucleus consists of quartzose grits belonging to the Mayhill sandstone or Upper Llandovery group. The trenches surrounding the central mass have been produced by the degradation of the more perishable beds, and the denudation of the harder rocks.‡

I must not conclude this brief sketch of the geological phenomena of the British Silurian series, without referring to the evidences of submarine and possibly sub-aerial volcanos having existed in Silurian times.§ During the period when the Llandeilo flags and their equivalents were accumulated over the area extending from the Malverns to Pembrokeshire, volcanic vents existed, whence molten matter and ashes were ejected, and became intermingled with the detrital accumulations of the period. The volcanic ashes were mixed up with the gravels and sands that are now in the state of conglomerates and sandstones, and accumulated in beds that are interstratified with the mud and sand. These igneous products were erupted prior to the granites of those districts.

The great peaked mountain-masses of Snowdon and Cader Idris, in Wales, are formed of Lower Silurian strata interstratified with contemporaneous volcanic grits, and traversed by subsequent dykes and pro-

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* See "Siluria." The quartz-pebbles so largely distributed over this part of England, and extending into the valley of the Thames, are water-worn fragments of the rocks composing this ridge; see p. 220.

† "Silurian System," p. 493. ‡ Ibid. chap. xxii. p. 488.

§ "Silurian System," chap. xxii. and xxvi. &c.; and Mem. Geol. Surv. vol. i. pp. 33 and 35.

trusive masses of igneous rocks. The strata of Cader Idris are Lingula-flags; those of Snowdon are Caradoc sandstone. Of the igneous rocks of the Upper Silurian period some notice has already been made at page 813.

In the Devonian strata also, near Tavistock and in South Devon, volcanic ash is intermingled with the argillaceous slates and limestones.*

17. Silurian and Cambrian strata of Europe and America.—Since the publication of the "Silurian System," much has been done to determine the position of the foreign sedimentary deposits formerly known to geologists by the general term of Transition-rocks; and, so far as recent observations have ascertained the characters and relations of the most ancient fossiliferous strata on the Continent, they are all referable to the same geological period as the Silurian and Cambrian formations of England.

In France † the oldest palæozoic rocks are Lower Silurian, which are succeeded by the Lower Devonian; the Upper Silurian being absent.

In Bohemia, especially around Prague, both Lower and Upper Silurian strata, often extremely rich in fossils, are largely developed; and have been admirably elucidated by M. Barrande.‡

Throughout Scandinavia § crystalline rocks occupy the surface of the country to a vast extent, and are covered in many places by sedimentary strata containing Silurian fossils. Near Christiania in Norway, the Lower Silurian deposits occupy a long trough in the gneissic rocks; and the little islands in the Bay contain Upper and Lower Silurian strata; the

* Mem. Geol. Survey Great Britain, vol. i. pp. 83 and 90.

† "Siluria," p. 383.

‡ "Système Silurien de la Bohème." Besides this noble result of his labours, in the form of the first volume (4to) of a magnificently illustrated and comprehensive work on the rocks and fossils of the Silurian basin of Bohemia, M. Barrande has published numerous papers and memoirs in the geological publications of Paris and Germany. A complete epitome of his views, ably drawn up by his friend, Sir R. Murchison, may be consulted in "Siluria." See also a full notice of M. Barrande's great work in the Annals of Nat. Hist. 2nd ser. vol. xii. p. 130.

§ See "Geology of Russia," &c. p. 10, &c.

entire series, with a multitude of typical fossils, being exhibited in very small areas.*

The Isle of Gothland exhibits a fine series of Upper and Lower Silurian rocks. Throughout a large part of the province of Scaraborg, in the south of Sweden, the Silurian strata are perfectly horizontal; the different subordinate formations of sandstone, shale, and limestone occurring at corresponding heights in hills many leagues distant from each other, with the same mineral characters and organic remains. It is clear that they have never been disturbed since the time of their deposition, except by such gradual movements as those by which large areas in Sweden and Greenland are now slowly and insensibly rising above, or sinking below, their former level.

In Russia and the Baltic Provinces† the lower division of the Silurian system is characterized, as elsewhere, by the abundance of Orthides, Leptænæ, and other brachiopodous shells, Orthoceratites, and Trilobites; the middle, by Pentameri; and the upper, by large masses of corals, especially of Favosites, Catenipora, &c.; and the Devonian strata teem with remains of the typical species of fishes, and with Spiriferi, Leptænæ, &c. Throughout the immense extent of Central Russia, forming nearly one-half of the European continent, there are no intrusions of igneous rocks; and the whole of the deposits, from the lowermost to the uppermost, are but little altered, and in many instances are unsolidified; yet each group contains the same typically characteristic organic remains as in England. But in the Ural Mountains and Siberia, the formations of the same age are thrown up into mural masses, broken into fragments, impregnated with metalliferous matter, and exhibiting every variety of metamorphic action.‡ Yet a clear distinction may nevertheless be drawn between these pseudo-igneous masses and the true ancient crystalline rocks on which the Silurian strata of Scandinavia rest.§

In North America a similar succession prevails; and we have thus proof that the modification, extinction, and renewal of species are not wholly attributable either to the alteration in the course of currents, or to the elevations or depressions of the ocean-bed, or to other more or less local causes, but depend on some general laws which govern the entire animal kingdom. It is, too, most remarkable, that in Russia, where the de-

* See Sir R. I. Murchison's Memoir on the Geology of Sweden, in Geological Society's Journal, vol. iii. p. 1; "Siluria," p. 316, &c.

† "Geology of Russia in Europe and the Ural;" and "Siluria."

‡ Quart. Journ. Geol. Soc. vol. xiv. p. 36, &c.

§ "Siluria," p. 437.

posits have gone on through immense periods without interruption, there are few species which pass from one series into another.

The Silurian series of North America is divided as follows:—

A. *Upper Silurian.* 1. Upper Pentamerus limestone; 2. Delthyris shaly limestone; 3. Lower Pentamerus limestone; 4. Waterlime rocks; 5. Onondaga salt-rocks; 6. Coralline limestone; Niagara shales and limestone. B. *Middle Silurian.* 7. Clinton rocks; 8. Medina sandstone; 9. Oneida conglomerate. C. *Lower Silurian.* 10. Hudson River rocks; 11. Utica slate; 12. Trenton limestone; 13. Bird's-eye limestone; 14. Chazy limestone; 15. Calciferous sandstone; 16. Potsdam sandstone; followed by the Huronian or Bottom Rocks of Canada.

Silurian strata form immense areas in North America, and constitute the grand ranges of the Alleghanies. In the Canadas they rest on gneiss and granitic rocks, like the equivalent deposits in Scandinavia and the North-west of Scotland. The Green Mountains of Vermont and the White Mountains of New Hampshire are composed of altered Silurian rocks.*

18. SILURIAN FOSSILS: PLANT-REMAINS.—The remains of about 1000 species † of animals have been discovered in the Silurian and Cambrian deposits of Britain, and of these, some are also present in the Devonian formation. Very few species only are common to the whole palæozoic system, and not one of these is known in any of the secondary deposits. The genera, however, have a much larger range. These remains almost exclusively belong to the invertebrata, the relics of fishes being comparatively rare; the large development of this class of vertebrated animals in the Devonian strata above is a remarkable zoological character of that period, for the general forms of the Silurian fauna, with this exception, are also found in that series.

* The admirable Geological State Surveys of North America, by Hitchcock, W. B. and H. D. Rogers, Hall, Conrad, Vanuxem, Dale Owen, Swallow, &c., and of Canada, by Sir W. Logan, contain full particulars of the palæozoic strata and their organic remains. See also the Memoirs by De Verneuil, D. Sharpe, Bigsby, Marcou, Lyell, and others; and especially the valuable chapter on the Palæozoic Rocks of South, North, and Arctic America, in "Siluria."

† Phillips, "Manual Geol." p. 128.

Vegetables.—Although beds and patches of culm, anthracite, and bituminous shale occur here and there in the lower palæozoic rocks * (Silurian and Cambrian), yet plant-remains are extremely rare. Indeed, it is not yet proved for certain that the old anthracitic schists owe their origin to the decomposition of masses of seaweeds, rather than of zoophytes,† and what have been regarded as fossil *Fuci* may often really be the casts of worm-tracks.‡ This is certainly the case with *Scolithus linearis* of the Potsdam sandstone and Lingula-flags,§ and probably with respect to the "Fucoides Harlani," abounding in the Silurian rocks of the Alleghany Mountains. The latter are short, curved, subcylindrical, wrinkled, overlapping bodies, sometimes forming entire layers, one hundred of which occur in a thickness of twenty feet.‖

It is in the Uppermost Silurian (Tilestone) only that, as yet, seed-vessels and woody relics of terrestrial vegetation have been found in England. These are of the Lycopodiaceous type.¶

In the flagstones of Mägdesprung,** in the Hartz, however, which are most probably of Upper Silurian age, M. Bischoff has discovered several specimens of plant-like fossils. Some at least of these appear to be portions of stems or branches, somewhat resembling those known under the names of *Knorria* and *Sigillaria* in the Devonian and Carboniferous strata.

19. SILURIAN ZOOPHYTES, ECHINODERMS, AND ANNELIDES.—The *Porifera* do not appear to have been frequent in the Silurian seas, if we are to judge by the general absence of

* See "Siluria," Appendix; Rep. Brit. Assoc. 1844, sect. p. 156, &c.

† See Harkness, Quart. Journ. Geol. Soc. vol. xi. p. 471.

‡ See above, page 808.

§ "Siluria," 2nd edit. p. 41.

‖ Dr. Harlan's "Medical and Physical Researches," p. 399.

¶ Strickland, Quart. Journ. Geol. Soc. vol. ix. p. 10; and Salter, *ibid.* vol. xiv. p. 76. "Siluria," 2nd edit. p. 267, *note*.

** Quart. Journ. Geol. Soc. vol. xi. p. 432.

fossil specimens. *Cliona*, however, has been observed in the Upper and Lower Silurian rocks of Britain and Bohemia. Prof. Ehrenberg has shown * that the grains of which the greensand associated with the Ungulite-grit of the Lower Silurian series of Russia and the Baltic Provinces is composed are in part at least the stony casts of the chambers of shells of primæval Foraminifera, not differing from those of later times.†

The *Oldhamia* occurs as small groups of radiated, fibrous or thread-like, wrinkly, raised or sunken lines on the surfaces of the beds; and at first sight appears like some marine Conferva. It is of obscure relations; but is valued as an interesting fossil, being abundant in the "Bottom-rocks" of Bray Head.

The corals, crinoids, and shells, in many of the Silurian rocks, are so numerous, and comprise so many interesting forms, that a reference to works expressly devoted to the subject can alone convey an accurate idea of this, the most ancient fauna of our planet, of which any vestiges have hitherto been obtained.‡

* Berlin Transact. for 1855, p. 172, pl. vi.

† See above, pp. 314 and 332

‡ The beautiful and accurate plates in Sir R. Murchison's "Silurian System," and repeated in "Siluria" (which latter work contains also numerous woodcut figures of palæozoic fossils), contain representations of a large proportion of the British species. Many others are figured in the Geol. Transactions and Journal; in Sowerby's "Mineral Conchology;" in Phillips's "Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset;" in Portlock's "Geological Report of Londonderry," &c.; in the "Geology of Russia and the Ural;" the Memoirs and Decades of the Geol. Survey; Sedgwick and M'Coy's "Synopsis of the British Palæozoic Rocks and Fossils;" M'Coy's "Synops. Sil. Foss. Ireland;" &c. The corals have been figured and described by Milne-Edwards and J. Haime. The noble palæontological volumes of James Hall, Dale Owen, and others of the United States geologists must be consulted for the fossils of North America. The Silurian fossils of Bohemia have M. Barrande for their accurate and persevering historian.

Of the corals, the Chain-coral (*Cateinpora* or *Halysites*, p. 653), *Omphyma* (p. 650), *Cyathophyllum*, and many large species of *Alveolites*, *Favosites*, *Heliolites*, &c., are among the prevalent forms. They abound mostly in the Wenlock group, and are often aggregated and cemented together into large masses of limestone, on the surface of which the stars or cells of the corals appear in relief. The slabs of Dudley (or Wenlock) limestone, embossed with these fossils, must be familiar to every intelligent observer; indeed, from the profusion of trilobites, shells, and corals displayed in relief on the surface of the slabs of this limestone, many of the specimens are of surpassing interest; they are, indeed, tablets of stone, inscribed with the typical hieroglyphics of the palæozoic ages.

The *Graptolites* * are peculiarly characteristic of the Silurian rocks. They are small, narrow, thin, saw-shaped fossils; straight, curved, or spiral; and either simple or complex in their stems and polyp-cells. They are often thickly scattered on the surfaces of flagstones. Generally black, sometimes bright grey (Sardinia), they catch the eye by the distinctness of their general form, though the strictest scrutiny of the naturalist is required to distinguish the varying characteristics of their protean structure. Whether they be allied to the existing Alcyonaria or to the Bryozoa, is undecided.†

Bryozoa ‡ are not unfrequent in the lower palæozoic rocks.

Members of the *Crinoid* division of the Echinodermata abound in the forms of *Actinocrinus*, *Cyathocrinus* (p. 664),

and those of Sardinia are beautifully figured in the magnificent work of De la Marmora. The Geological Society of France also have published many Memoirs illustrative of the palæozoic fossils of France, Spain, &c.

* Medals, p. 255. Barrande, Scharenberg, Geinitz, J. Hall, Salter, M'Coy, and Harkness have of late years especially studied and illustrated the Graptolites. See also "Siluria," chapt. 3.

† See pp. 614 and 629. ‡ See above, pp. 601 and 611.

&c., chiefly in the Upper Silurian beds. The *Cystoidea* are numerous; especially *Caryocystites*, *Echinosphærites*, and *Pseudocrinites* (p. 666). The Starfish-group also is well represented by several species * of *Palæaster*, *Palasterina*, *Palæocoma*, *Bdellacoma*, *Rhopalocoma*, *Protaster*, *Palæodiscus*, and *Lepidaster*, with the echinoid *Palæchinus*.

Annelides † have left abundant proofs of their existence throughout the Cambro-Silurian series. The *Scolithus* and *Arenicolites* are their burrows; and numerous trails and casts of tracks and holes are also found. These have been in some cases distinguished by names, and not unfrequently they have been taken for the remains of fucoids. Shelled annelids, such as *Spirorbis*, *Tentaculites*, and the ambiguous *Cornulites*, often abound. The two last are characteristic fossils.

20. Silurian Molluscs.—The Brachiopodous Mollusca constituted a very large proportion of the population of the Silurian seas.‡ They attained great numbers, as genera, as species, and as individuals. Species of *Atrypa*, *Discina*, *Leptæna*, *Lingula*, *Orthis*, and *Rhynchonella* abounded. *Porambonites*, *Siphonotreta*, and *Obolus* occur in the Silurian rocks only. Some of the middle beds (Llandovery group) are full of *Pentameri*. The genus *Lingula*, which affords some species characteristic of the lower part of the Llandeilo-rocks (Lingula-flags) and the equivalent Potsdam-sandstone, *Rhynchonella*, *Crania*, *Discina*, and probably *Terebratula*, appear in the Silurian rocks, and are present in all the successive groups of palæozoic, secondary, and tertiary strata, and even in the present seas.§

The Potsdam-sandstone, the most ancient fossiliferous

* Salter, Annals Nat. Hist. 2nd ser. vol. xx. p. 321.

† Medals, p. 503

‡ M. Barrande has determined 200 species in Bohemia.

§ See Mr. T. Davidson's highly valuable "Synoptical Arrangement of the Recent and Fossil Brachiopoda," Annals Nat. Hist. 2nd ser. vol. xvi. p. 429.

rock of North America, is in many places divided into laminæ by the remains of innumerable shells of the genus *Lingula*. They are in such profusion as to form black seams like mica, and are accompanied with another small placunoid shell, which is also associated with a small species of *Lingula* in the lowest beds of the Llandeilo series of Wales. Here, then, in the most ancient term of organic life is a shell belonging to a genus not extinct, and very like a species still living.*

A species of *Ungulites* or *Obolus* (a small orbicular horny shell) occurs in the inferior limits of the fossiliferous deposits in Russia,† occupying the same geological position as the *Lingulæ* in the Lower Silurian beds of Wales and North America above cited.

Ambonychia, Avicula, Pterinea, Arca, Cleidophorus, Modiolopsis, Nucula, and *Orthonota* are most of the principal bivalves. The *Pteropoda,* such as *Conularia*‡ and *Theca,*§ were plentiful; and of large size, compared with the existing species. Of *Gasteropoda* there were numerous forms: *Euomphalus, Holopella, Murchisonia, Pleurotomaria,* and some shells resembling the recent *Trochus* and *Turbo,* were predominant. *Acroculia* (like a *Capulus*) was not unfrequent in some localities, and attained a large size.‖ Chiton-like gasteropods (*Helminthochiton*) also existed. The *Bellerophon,* a genus which, like many of its associates, lived on into the Carboniferous seas, had many species in the Silurian. The *Cephalopoda,*¶ however, were the master-forms** of

* Lyell's "Travels, N. America," vol. ii. p. 157

† "Geology of Russia," vol. ii. p. 292.

‡ Specimens more than a foot long are preserved in M. Barrande's invaluable collection of Bohemian fossils.

§ In the Lower Silurian, five inches is a not unusual length for the *Thecæ;* they are smaller in the Upper Silurian: the living species are of microscopic size.—*Barrande.*

‖ Five inches long, in Bohemia.—*Barrande.*

¶ Medals, p. 417.

** Nearly 300 species, some of them of large forms, occur in Bohemia. —*Barrande.*

these primeval seas. In Britain alone nearly sixty species of Silurian *Orthocerata* are known: in the Bohemian basin M. Barrande has worked out very many more; besides many other genera, some almost as rich in species. M. Barrande has met with at least two specimens of Orthoceras in which remains of the soft parts are still present, in the condition of a soft, waxy, yellowish-brown, adipocire-like substance.* Some specimens of Orthoceras attained a large size, being three feet in length, and having seventy septa.

Goniatites do not occur in the British Silurian strata; but are present (fourteen species) in those of Bohemia, where other fossils of a "Devonian" character are mingled with those of the "Upper Silurian." M. Barrande has found indications of the original colours of the shells retained on eight or ten specimens of Silurian cephalopods of Bohemia.

Lituites, *Phragmoceras*, *Cyrtoceras*, and *Ascoceras* are the remaining genera of the British Silurian cephalopods.†

21. Silurian Crustacea.—The higher or Malacostracous members of the Crustacean order do not appear in the lower palæozoic rocks. The Entomostraca, however, abound. The *Pterygotus*, allied to the Limulus, but more nearly resembling one of the Lobster family in outward form, occurs in the Lower Ludlow,‡ with *Limuloides*, and again in the uppermost of the Ludlow beds, as well as in the Old Red and Lower Carboniferous, as already mentioned. *Hymenocaris* is a bivalvular phyllopod, somewhat resembling a Nebalia, and is one of the oldest of known organic remains. *Ceratiocaris*, another bivalved crustacean, with protruded

* For this and much other interesting information respecting the Silurian fossils of Bohemia, the Editor is indebted to the kindness of M. Barrande.

† The Editor takes this opportunity of acknowledging, with much pleasure, the great assistance he has derived throughout this work from Prof. Phillips's Synoptical Tables of Fossil Genera ("Manual of Geology," 1855), carefully constructed from Morris's "Catal. Brit. Foss.," 1854.

‡ Salter, *Annals N. H.* 2nd ser. vol. xx. p. 321

tail, belongs to the Upper Silurian. Small bivalved entomostraca, such as *Beyrichia* and *Leperditia*, occur both in Lower and Upper Silurian rocks, and often in great numbers.

Track-marks, referred to Limuloid crustaceans, and termed *Protichnites*,* have been founded in the Potsdam-

LIGN. 182.—TRILOBITE IN SILURIAN LIMESTONE FROM DUDLEY.
(*Calymene*† *Blumenbachii.*)

sandstone of Canada,‡ in the Clinton rocks of the United States,§ and in the Lower Silurian of Scotland:∥ others, referred by Mr. Salter to the *Hymenocaris*, have been found by him in the Lingula-flags of North Wales.¶

* *First-tracks.*

† *Calymene*, signifying concealed: in allusion either to the obscurity of its zoological relations when first studied, or to the non-discovery of legs and antennæ.

‡ Logan and Owen, Quart. Journ. Geol. Soc. vol. viii. pp. 199 and 211.

§ Desor and Owen, *loc. cit.* p. 213.

∥ Harkness, Geol. Soc. Journ. vol. xii. p. 243.

¶ Quart. Geol. Journ. vol. x. p. 208.

*Trilobites.**—But the most extraordinary feature in the Cambro-Silurian fauna is the abundance and variety of the

LIGN. 193.—ENCRINURUS PUNCTATUS, FROM DUDLEY.
(The head is here imperfect.)

LIGN. 194.—PHACOPS CAUDATUS, FROM DUDLEY.
(Tail-portion.)

LIGN. 195.—HOMALONOTUS DELPHINOCEPHALUS, FROM THE WENLOCK ROCKS.
(Reduced from Pl. VII. bis, fig. 1, Sil. Syst.)

Trilobites,—a peculiar family of Crustaceans, of which there are no living representatives, and which is restricted to the

* *Trilobites,* signifying "three-lobed," from the general form of the carapace or shell.

palæozoic formations, and almost exclusively to the most ancient fossiliferous deposits; for, while the Silurian rocks teem with the relics of hundreds of species,* but few, comparatively, occur in the Devonian and Carboniferous.

These remarkable crustaceans had the body protected by a strong dorsal case or shell composed of numerous annular segments, and generally divided into three lobes by two longitudinal furrows or depressions. The head and the tail are each covered by a single piece. The eyes of most of the genera are very large and reticulated, consisting of numerous distinct facets or lenses, as in other crustaceans, and are implanted on the cephalic buckler. No traces of pats, feet, or swimmers have been detected, and it is therefore supposed that these appendages were composed of a soft and perishable substance.†

One of the most common species of Trilobite is the *Calymene Blumenbachii*, commonly known as the "Dudley fossil Insect" or "Locust," and which has long attracted the attention of collectors; ‡ this crustacean is found either attached by the under surface to the rock, as in *Lign.* 192, or coiled up like an Oniscus, or wood-louse.§ Some kinds, as the *Calymene*, could coil themselves into a ball like the wood-lice; while others had the central segments alone moveable. The Trilobites vary exceedingly in form and magnitude; some not exceeding a few lines, while others are eighteen or twenty inches in length.

* In Bohemia alone 252 species have been recognised by M. Barrande. See his richly illustrated work on the Silurian Basin of Bohemia.

† See Medals of Creation, pp. 532—542, for an account of the Trilobites, and for references to monographs and descriptions. The notices of the Trilobites in Sir R. Murchison's "Siluria" must, however, be carefully consulted, as comprising the latest and most complete account of the distribution of this genus.

‡ This Trilobite was figured and described by Lhwyd in 1698.

§ Medals of Creation, p. 533 (Lign. 175, fig. 4).

The Trilobites of the genera *Agnostus*, *Conocephalus*, *Olenus*, and *Paradoxides* characterize the lowest fossiliferous schists: *Æglina*, *Amphion*, *Asaphus*, *Cybele*, *Cyphoniscus*, *Harpes*, *Illænus*, *Ogygia*, *Remopleurides*, *Trinucleus*, &c. belong to the Llandeilo and Caradoc beds: *Acidaspis*, *Proetus*, &c. have more Upper than Lower Silurian species. *Calymene*,* *Cheirurus*, *Cyphaspis*, *Encrinurus*, *Homalonotus*, *Lichas*, *Phacops*, and other genera range from the lower to the upper part of the series.

According to the late researches of Prof. W. B. Rogers,† the gigantic *Paradoxides Harlani* characterizes the metamorphic schists of Braintree (Eastern Massachusetts), flanking the Alleghanies, ten miles south of Boston, and indicates their age to be that of the Lingula-flags of Wales, M. Barrande's "zone primordiale" of Bohemia, and the Potsdam-sandstone and the Dikelocephalus-sandstone of North America.

22. Visual Organs of the Trilobites. — That any traces should remain of the visual organs of animals which existed at so remote a period seems at first incredible; but there are no limits to the wonders which Geology unfolds to us.‡

The eyes of the Trilobites resembled in structure those of crustaceans and insects, which are composed of a vast number of elongated cones, each having a crystalline lens, pupil, and cornea, and terminating on the extremity of the optic nerve. Each organ of sight is, therefore, a compound instrument, made up of a series of optical tubes, or telescopes, the number of which in some insects is quite marvellous. Thus, each eye

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* *Calymene Blumenbachii* occurs both in the Caradoc or Bala beds of Snowdon and in the Wenlock limestone.

† Boston Nat. Hist. Soc. Proceed. vol. vi. pp. 27 and 40. See also *ibid.* p. 140, for Prof. H. W. Rogers's remarks on the classification of the Metamorphic rocks of the Atlantic slope of the Middle and Southern States.

‡ The structure of the eye of the Trilobite was, I believe, first noticed by that accurate observer, Mr. Martin, the author of "Petrif. Derbiensia;" it is illustrated in the "Histoire Naturelle des Crustaces Fossiles," par A. Brongniart et G. A. Desmarest, Buckland's "Bridg. Treat.," the "Decades of the Geol. Survey," Barrande's "Syst. Silur. Bohème," vol. i. (Trilobites), and in Burmeister's "Organiz. Trilob." The cornea in the Trilobites is said by Burmeister to have an external smooth integument, which covers over the facets of the aggregation of lenses of which the eye consists, as in the *Branchipus*.

of the common house-fly is composed of eight thousand distinct visual tubes; that of the dragon-fly, of nearly thirteen thousand; and of a butterfly, of seventeen thousand. The Trilobite, like the Limulus, was furnished with two compound eyes, each being the frustrum of a cone, but incomplete on that side which is opposite to the other. In *Phacops* upwards of 200 lenses have been detected in each eye; but in general the lenses have fallen out, as often happens after death in the eyes of the common lobster. The eyes of *Æglina* are very large, and each eye contains more than 1500 facets; but the eye of *Brontes palifer* presents more than 30,000 facets (Barrande). Thus, observes Dr. Buckland, we find in the trilobites of these early rocks the same modifications of the organ of sight as in the living crustaceans. The same kind of instrument was also employed in the intermediate periods of our geological history, when the secondary strata were deposited at the bottom of a sea inhabited by Limuli, in those regions of Europe which now form the elevated plains of central Germany. But these results are not confined to physiology: they prove also the ancient condition of the seas and atmosphere, and the relation of both these media to light. For in those remote periods the marine animals were furnished with instruments of vision in which the minute optical adaptations were the same as those which now impart the preception of light to the living crustacea. The mutual relations of light to the eye, and of the eye to light, were, therefore, the same at the time when crustaceans first existed in the bottom of the Silurian seas as at the present moment.*

23. SILURIAN FISHES.—Of the vertebrate animals, the relics of a few species of small placoid fishes, and a few others of the ganoid group and cephalaspid family,† found in the Upper Ludlow rocks, are the only vestiges hitherto obtained from the immense series of strata composing the Silurian system (of Murchison),—the Silurian and Cambrian series of Sedgwick.

From the presence of *Cephalaspis* (afterwards so plentiful in the Old Red Sandstone) amongst these Ichthyolites, and

* Bridgewater Treatise, pp. 398—404, where the subject is ably elucidated, and placed before the reader in a striking point of view.

† See Table, p. 802. For the latest information respecting Silurian fish-remains, see Quart. Geol. Journ. vol. ix. pp. 12 and 16; *ibid.* vol. xiii. pp. 282 and 290; and "Siluria."

their association with *Pterygotus*, which also becomes abundantly developed in the Forfarshire shales, the uppermost Ludlow rocks of Britain evidently mark the transition from the Silurian to the Devonian epoch: that is, these beds were being deposited during the period (probably of great duration) when, coincidently with some important reärrangement in the distribution of land and sea, the precursors of new tribes of animals advanced upon the shallowing area of the old sea-bed, before the existence of the ancient forms of life was terminated.

Most of the ichthyolites occur in two thin brownish bands, called "the Ludlow Bone-beds;" the lower one of which, though only a few inches thick, has been traced for more than forty miles. It consists mainly of animal detritus, namely, the bones, teeth, scales or shagreen, fin-bones, and coprolites of small fishes. This deposit resembles the bone-bed * at the base of the Lias.

24. STRUCTURE OF SLATE-ROCKS.—Many of the older palæozoic rocks of Britain, America, and elsewhere have been not only hardened by chemical and mechanical agencies, but converted into shivery or schistose rocks, traversed by numerous joints; and sometimes they are separable into thin regular plates or slates. These changes have taken place, also, in some of the Devonian and Carboniferous rocks; and, in the Alps and other places, even the Cretaceous and Tertiary rocks have been similarly altered.

Schists and slates almost universally occur on the flanks of mountain-masses, rising up into lofty peaks, and dipping beneath the newer sedimentary deposits: thus Skiddaw, Sea-fell, Coniston-fell, and Saddleback in Cumberland, peaks 3000 feet high, are schistose and slaty rocks thrown up by a central mass of granite.

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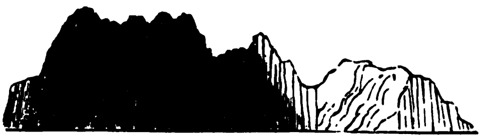
* See p. 524. This latter bone-bed, having much the same relation to the Trias as the Ludlow bone-beds have to the Silurian, has been traced for upwards of *forty miles* in the West of England, besides having been recognised over a wide area in Germany.

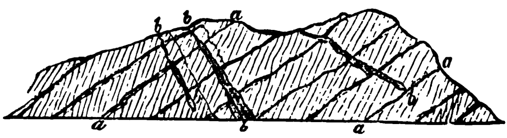
Shales are either hard or soft argillaceous rocks, easily splitting along the planes of bedding or of sedimentary deposition; *Schists* are hard rocks, of argillaceous or silicious composition, which are laminated and shivery chiefly along the planes of bedding; in *Slates*, on the contrary, the laminated structure is due to divisional lines, called planes of *cleavage*, which *traverse* the planes of bedding, in what were originally strata of fine argillaceous sediment.

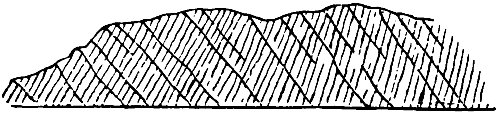


LIGN. 196.—SLATE-ROCKS AND GRAPTOLITE-SCHISTS AT ABERREIDDY BAY, NEAR ST. DAVID'S, PEMBROKESHIRE. ("Silurian System," p. 399.)

The lines of cleavage and stratification coincident.)

1





2

LIGN. 197.—SECTIONS OF SLATE-ROCKS.

Fig. 1. Section near Llandovery. Quartzose grit and sandstone; *a*, *a*, planes of bedding; *b*, *b*, quartzose veins. The highly inclined lines mark the planes of slaty cleavage.
Fig. 2. Section of slate-rocks at Whitesand Bay, Pembrokeshire; the cleavage and lines of stratification divergent.

It is often difficult to define schistose and slaty rocks; and there are also rocks distinguished from either by their lines of division (often set widely apart) being termed planes of *foliation*, such as are seen in most of the gneissose rocks. The fineness of grain, general aspect, hardness, and texture of true slates (roofing-slate) are too well known, from the universal employment of slate for economical purposes, to require particular description. The colour usually approaches to blue, grey, green, and a dull purple; and the texture is very fine, although occasionally the slate passes into sandstone and greywacke; for, as clay-beds, sandstones, and conglomerates succeed, or alternate with, each other in later formations, so clay-slate occasionally passes into varieties of greywacke, which are indurated sandy and gritty strata, often containing ragments of still older slates and crystalline rocks, and, from the nature f their composition, not susceptible of the infinite and regular cleavage hat the clay-rock has undergone.

In some instances, the lines of cleavage are in the same plane as those f the strata, as in the section (*Lign.* 196); but commonly the cleavage s in a different direction to the stratification, the respective lines crossing ach other at various angles. In the quartzose grit and sandstone of Llandovery (*Lign.* 197, *fig.* 1), and in the slate-rocks at Whitesand Bay n Pembrokeshire (*fig.* 2), the discrepancy between the lines of deposiion and of cleavage is strongly marked.

This peculiar laminated structure is common to many rocks which are roved, by their contained fossils, to be of sedimentary origin. The direcon of the laminæ or cleavage-planes, with respect to the stratification f a given rock, differs exceedingly in different places; these being oftntimes at right angles to each other (*see Lign.* 197, *fig.* 2). Hence it ollows that this remarkable structure must be wholly independent of deosition. Prof. Sedgwick has regarded it as being due to a kind of dull rystalline action on an enormous scale. Prof. Phillips and Mr. D. Sharpe ave shown that, chiefly from the changes of form that fossils have unergone in some cleaved rocks, mechanical force, applied laterally, nd connected probably with the uplift of mountain-masses, has had nuch to do with the origin of cleavage, in conjunction perhaps with the rystalline action suggested by Sedgwick. And lastly, Sorby has demontrated that the intimate particles of clay-slate and other slaty rocks ave been absolutely shifted, by mechanical force, from their original ositions, in which they were deposited as sediment, into new positions n which they are set parallel to each other, and arranged in lines and laminæ, giving rise to innumerable lines or planes of relative weakess in the rocky mass, along which it may be easily split; the old nes of bedding being more or less completely obliterated by the change f structure. The *foliation* of the gneissic rocks is partly due to a milar cause; and partly, it appears, to those chemical alterations, on an enormous scale, which the rocks in contiguity to the deep-seated igneous masses have suffered, and, probably, are still undergoing.*

25. Review of the Lower Palæozoic Series.—In conclusion, I will briefly review the leading phenomena which have been brought under our notice in the course of this Lecture.

The strata comprised in the Silurian or Cambro-Silurian series present all the usual characters of marine sedimentary deposits. The fossils comprise traces of marine worms throughout the series, many corals, chiefly in the upper limestones, numerous crinoids, immense numbers of extinct forms of the lower crustacean tribes, and of brachiopodous mollusca, with many of the lamelli-branchiate, gasteropodous, pteropodous, and cephalopodous families. The fishes come in late in the series, together with scanty relics of terrestrial plants. The marine vegetation of the period is indicated only by obscure fucoidal markings, and possibly by the occasional anthracitic and bituminous bands of the lower rocks. These organic remains belong, for the most part, to peculiar generic types, mostly ranging throughout the fossiliferous Cambro-Silurian strata, and some extend into the upper palæozoic formations, but none occur in the secondary deposits.

In fine, the lower palæozoic rocks (the "Silurian and Cambrian," of Sedgwick, or "Upper Silurian, Lower Silurian, and Bottom-rocks," of Murchison) have resulted from marine depositions, going on through immense periods of time, in seas swarming with zoophytes, crinoids, crusta-

* The papers by Sedgwick and D. Sharpe, on Cleavage, are to be found in the Geolog. Transact. and Journ.; Mr. Sorby's papers in the Phil. Mag. and Edinb. N. Phil. Journ. Their researches, together with those of Darwin, Hopkins, Tyndall, Rogers, Haughton, and others, are admirably collected and illustrated by Prof. Phillips, in his "Report on Cleavage," to the Meeting of the British Assoc. 1857. See also Sir R. Murchison's concise résumé of the facts and hypotheses relating to the interesting subject of Cleavage, in "Siluria," 2nd edit. chapter 2. For some remarks on Metamorphism of Rocks, see further on, Lect. viii. *part 2.*

ceans, and molluscs, and ultimately with fishes. Much of the lower portion of this great sedimentary series has been subjected, since its original deposition, to metamorphic influences, by which the sedimentary characters have been either greatly modified or entirely obliterated; still some of the "bottom-beds" (Longmynd) are even less altered than great portions of the succeeding groups of Llandeilo and Caradoc.

Some eminent geologists are of opinion, that there is a line in the descending series of strata, where organic remains entirely disappear; and that this line is by no means coördinate with mineral changes induced by igneous action. As regards the absence of fossils in the porphyriferous schists of Llandeilo age, it may be in part attributable to the obliteration of all vestiges of organic remains, in consequence of the high temperature to which they have been exposed; or animals may not have been capable of living in an ocean subjected to continual incursions of igneous matter. But the bottom-rocks are sometimes not so much altered but that fossils might be detected in them, if present; and this, to some extent, has been put to the proof, at Bray Head and the Longmynd, by Dr. Kinahan and Mr. Salter,* who have thus extended our knowledge of primeval animated nature into periods once thought to be "azoic." What further glimpses into the natural history of the primordial regions we shall obtain, the persevering and active researches of intelligent collectors will alone show.

With the *Oldhamia* of Ireland, the *Palæopyge* of the Longmynd, and their associated *Arenicolites*, we lose at present all positive evidence of the presence of organic beings on the surface of the primordial earth; but it would be rash to assume that these most ancient fossils are the relics of the earliest living things that tenanted our planet. Well has Sir C. Lyell remarked, that "it is too common a fallacy to fix the era of the first creation of each tribe of plants or animals, and even of animate beings in general, at the precise point where our present retrospective knowledge happens to stop." †

* See above, p. 808.

† See also "Travels in North America," vol. ii. p. 128, &c.

LECTURE VIII.

PART II.—THE VOLCANIC AND HYPOGENE ROCKS.

1. Introductory. 2. Nature of Volcanic Action. 3. Earthquakes. 4. Earthquake of Lisbon. 5. Phlegræan Fields, and the Lipari Isles. 6. Ischia and Vesuvius. 7. Structure of Volcanic Mountains. 8. Volcanic Products. 9. Lava-currents, Dykes, and Veins. 10. Eruptions of Vesuvius. 11. Herculaneum and Pompeii. 12. Conservative effects of Lava-streams. 13. Organic Remains in Lava. 14. Mount Etna. 15. Val del Bove. 16. Volcano of Kilauea. 17. Mr. Stewart's visit to Kilauea. 18. Volcano of Jorulla. 19. Submarine Volcanos. 20. Summary of Volcanic Phenomena. 21. Hypogene Rocks. 22. Mica-schist and Gneiss. 23. Contorted Crystalline Rocks. 24. Basalt or Trap. 25. Isle of Staffa. 26. Strata altered from contact with Basalt. 27. Trap-dykes in the Isle of Sky. 28. Granite. 29. Granitic Eruptions. 30. Metamorphism of Rocks. 31. Precious Stones. 32. Metalliferous Veins. 33. Auriferous Alluvia. 34. Cupreous Deposits. 35. Transmutation of Metals. 36. Review of the Hypogene Rocks. 37. Organic Remains in metamorphic Rocks. 38. Chronology of Mountain-chains. 39. Systems of Elevation. 40. The Great Caledonian Valley. 41. Structure of Ben Nevis. 42 Retrospect. 43. Successive changes in the Organic Kingdoms. 44. Geological effects of Dynamical and Chemical Action. 45. Strata composed of Organic Remains. 46. General Inferences. 47. The Ancient World. 48. Corollary. 49. Final Effects. 50. Concluding Remarks.

1. Introductory.—We have now passed the boundary which separates the animate from the inanimate world, and have entered those regions of geological research in which all traces of organized beings are absent, and various modifications of mineral substances are the only objects that meet our view. The rocks no longer exhibit those organic characters by which we were enabled to decipher the natural records of the past, entombed in the fossiliferous strata; but they are inscribed with hieroglyphics whose meaning is often obscure and frequently unintelligible, and many of which admit of a double interpretation.

The [illegible]al effects of water as a fluid, everywhere so uni[illegible] mentary formations, are no longer apparent; but the powerful agency of the same substance in the several conditions produced by high temperature—as vapour, steam, and gas *—is universally exhibited in the upheaved mountain-chains, the protruded igneous matter, the rent and dislocated rocks, and the rugged peaks and precipitous glens, which are the characteristic features of the physical geography of schistose and granitic regions.

In the phenomena attendant on the earthquakes and volcanos of modern times, we have proofs of the continued energy of those physical forces which produced the results that will form the principal subjects of this discourse. The nature and effect of volcanic action (to which we have previously and incidentally alluded) now, therefore, demand our especial consideration, in order that we may comprehend the origin and formation of the metamorphic and plutonic rocks; or in other words, of those mineral masses which have acquired a crystalline structure from exposure to the influence of intense heat under great pressure, and have been elevated into their present position by subterraneous movements. I propose, in the first place, to consider the nature and effects of igneous action as exhibited in existing volcanos; secondly, to describe the hypogene or plutonic rocks, and the changes produced in contiguous mineral masses by their influence; and, lastly, to offer a few general remarks on some of the most important subjects that have engaged our attention.

2. Nature of Volcanic Action.† — Volcanic action

* The beautiful experiments of Mr. Grove prove that water may be reduced to its elementary compounds—oxygen and hydrogen—by intense heat alone. See Philos. Trans. 1846.

† Daubeny, Darwin, Scrope, and Lyell are chief among the English geologists who have made the causes and effects of volcanos a special study. The Transactions and Journal of the Geological Society are enriched with several of their Memoirs; and the special works of Scrope and Daubeny on Volcanos ought to be in the hands of the student. In the appendix to the second edition of Dr. Daubeny's comprehensive and invaluable "Description of *active* and extinct Volcanos, of Earthquakes,

is referred by Humboldt to the influence exerted by the internal heat of our planet on its external surface; by which concussions of the land, or earthquakes, and the expansion or elevation, and the subsidence or contraction, of large portions of the solid crust of the earth have been produced. The number of existing volcanos is estimated at about 200, of which 116 are situated in America or its islands.

In the previous discourses, many of the effects of igneous agency came under our notice,* namely, the subsidence and elevation of the Temple of Serapis (p. 106), the gradual rise of Scandinavia (p. 116), the upheaving of the sea-coast of Chili (p. 112), and other mutations of a like nature. As we successively examined the tertiary, secondary, and palæozoic or primary formations, proofs that similar phenomena had taken place during every geological epoch were equally manifest; the geographical distribution of the foci of volcanic action was found to have varied, but throughout the cycle of physical changes contemplated by Geology, the volcano and the earthquake appear to have been in ceaseless activity.

and of Thermal Springs, &c.," will be found a full and classified list of British and foreign works on the same subjects previous to 1848. The first volume of Humboldt's inimitable "Cosmos" has a section devoted to the subject of Volcanic phenomena, and supplies many references to Von Buch, Arago, Bischof, Prévost, Gay Lussac, and other continental authors. Abich, Deville, de Beaumont, Dolomieu, and Scacchi are other European geologists who have written valuable treatises on Volcanos; and Dana heads the list of American volcanists. Earthquakes and their associated phenomena have necessarily been treated of by many of the above-named geologists; but M. A. Perrey, of Dijon, and Mr. Mallet, of Dublin, have especially taken up the subject, in some of its aspects; the results of the researches of the latter will be seen in the Reports of the British Association; the publications of M. Perrey may be found in the Memoirs of the Scientific Societies of Paris, Lyons, Brussels, &c. The student is particularly recommended to read the chapters on Volcanic Rocks and Action, in Lyell's "Manual of Geology," 5th edition.

* A concise view of the effects of high temperature and of volcanic action on the earth's crust was given in the first Lecture, vol. i. p. 103.

The immediate cause of volcanic action has been referred some to the operation of *heat produced by chemical agency*, ch as the combustion of sulphureous or carbonaceous sub- nces, or the combination of oxygen with the metallic ses of certain alkalies and earths; whilst others refer vol- ic action to the *actual existence of a very high temperature*, th incandescent and molten mineral matter, beneath the ıst of the earth.* The following are the evidences of the istence of the *central heat*. If the globe consisted of a id rock, such as granite, it is calculated that its specific vity would be greater than what astronomers find it to ; and it is therefore assumed, that the expansive power of at must be present to resist the compression arising from vitation to the centre. A constantly increasing tempera- e of the interior, according to the distance beneath the rface of the earth, is found to exist, from observations in nes and on the waters of deep wells. The heat of many neral springs, the outbursts of the volcanic rocks them- ves, and the alterations which deep-seated strata have ffered apparently from the action of heat, are also regarded direct evidences of a greatly heated condition of the earth's terior.

This high temperature of the interior, whatever may be origin, is the germ not only of earthquakes, which are e purely dynamical effects of volcanic action, but also of e gradual elevation of continents, and of chains of moun- ins from extended fissures; giving rise to eruptions of va, mud, boiling water, &c.,—to thermal mineral springs, and halations of steam, carbonic-acid gas, sulphurous vapours, .,—and the production of various rocks and minerals. the earlier ages of the globe the phenomena appear to ve been of greater extent and in a higher degree of inten y than in modern times.

3. EARTHQUAKES.—The tremblings or vibrations of the

* See p. 34; Cosmos, vol. i. p. 152

solid crust of the globe, denominated Earthquakes, are vertical, horizontal, or gyratory oscillations of the land rapidly succeeding each other; and are caused by the expansive efforts of elastic fluids confined in subterraneous cavities. The craters of volcanos are the vents through which the imprisoned gases and vapours, and the incandescent mineral matter, force their way to the surface: they are, in fact, the safety-valves of the vast reservoirs of gaseous elements which are contained in the profound depths of the earth. Hence, if the action of a volcano be impeded, earthquakes are commonly induced, and the equilibrium of the land is not restored until the crater resumes its activity, or the imprisoned gases escape through other channels.* A column of smoke which was seen for some months to rise from the volcano of Pasto in South America suddenly disappeared, when, on the 4th of February, 1797, the province of Quito, 192 miles to the southward, was visited by the great earthquake of Riobamba.†

The focus of volcanic action must be at an immense distance from the earth's surface, though no rational conjecture can be formed either of its depth or of the chemical nature of the compressed fluids: but the vast areas over which the undulations sometimes extend are proofs of the tremendous power of these subterranean forces.

4. Earthquake of Lisbon.—The earthquake of Lisbon, in 1775, which suddenly destroyed 60,000 persons, was the most extensively felt of any on record. Its effects were perceived over the whole of Europe, the North of Africa, and in the West Indies: and it is computed that a portion of the earth's surface four times the extent of Europe was simultaneously affected. The enormous undulations of the sea by which it was followed, and that swept along the

* The explosion of a steam-boiler from the closure of the safety valve is a familiar example of this phenomenon.

† *Humboldt's* Cosmos, vol. i. p. 211.

coasts of Spain, Portugal, and Africa, are supposed to have arisen from the sudden upheaval or subsidence of a vast area of the bed of the Atlantic Ocean, beneath which the principal focus of the subterranean disturbance appeared to be situated. The effects of this earthquake were felt in many parts of England, Scotland, and Ireland, and even as far as Norway: the waves occasioned by the concussion reached our southern shores; and the waters of Loch Ness, and of other inland lakes (at Salzungen, for instance), were simultaneously agitated. Even the thermal springs of countries remote from the catastrophe were affected; those at Toplitz in Bohemia, which for centuries had flowed in a pure and equal stream, suddenly ceased, and then burst forth in a flood of turbid water of a very high temperature.

Humboldt remarks, that it is probable that the earth's surface is always disturbed at some one point, and that it is incessantly affected by the reaction of the interior against the exterior. The permanent elevation of extensive tracts by earthquakes sometimes take place; as on the coast of Chili, in 1822 (p. 112), and in New Zealand, 1855; and they are often accompanied with eruptions of mud, steam, hot water, carbonic acid gas, and other elastic fluids

The present grand European centre of volcanic action is in Southern Italy, which has for ages been in a state of energy; Etna, Vesuvius, and the Lipari Isles being the vents through which the incandescent materials have escaped.

5. The Phlegræan Fields and Lipari Isles.—The volcanic region of Naples consists of a linear group of cones, ranging N.E. and S.W., and terminating at its extremities by the two principal mountains, Ischia and Vesuvius; the latter seems to be connected by the intervention of minor vents with the group of Albano and of Rome; the seven hills of the Eternal City being for the most part volcanic mounds.*

* *Mr. G. Poulett Scrope*, Geol. Trans. 2nd ser. vol. ii. p. 337. In the

The district of Puzzuoli and Cumæ, on the Bays of Baiæ and Naples, is called the Phlegræan Fields, and in it are situated Monte Nuovo, Monte Barbaro, the Solfatara, and the Temple of Serapis. This tract presents a series of cones and crateriform basins; some of which contain lakes, as those of Avernus and the Lucrine. These volcanic mounds are formed of felspathic tufa, occasionally containing marine shells and carbonized wood, and are covered by beds of loose tufaceous conglomerate. They are supposed by Mr. Scrope to have been produced by numerous submarine eruptions, each from a fresh focus, on a shallow shore.*

The volcanic cone termed the SOLFATARA, so well known from its incessant emission of torrents of aqueous and sulphurous vapour, through superficial fissures, is recorded as having been in a state of activity in the year A.D. 1180. Mr. Scrope supposes the present crater to have been formed at that period; and he attributes the constant emanations of sulphuretted hydrogen to the effect of a mass of lava still existing beneath at an intense temperature. The chemical changes effected by the immediate conversion of this gas into sulphuric acid, from combination with the oxygen of the atmosphere, and the subsequent action of the acid on the tufas, trachytes, &c., giving rise to sulphates of alumine, iron, lime, magnesia, soda, &c., while the silex is left nearly pure in the state of a white earthy powder, are in the highest degree interesting.†

The earthquakes of 1538, which were followed by an eruption of mud, pumice-stone, and ashes that burst forth from a gulf near the town of Tripergola, and formed the volcanic mound called Monte Nuovo, and by the permanent elevation of the coast to beyond Puzzuoli, were mentioned in a former Lecture (p. 108).‡

Quart. Journ. Geol. Soc. vol. vi. p. 281, &c., is a most interesting paper by Sir R. Murchison, "On the Earlier Volcanic Rocks of the Papal States," referring to the labours of Italian geologists, and especially treating of the tracts north of Rome,—the travertines, past and present,—the volcanic rocks of Latium,—and lastly, the probably subaqueous origin of these volcanic ejectamenta and craters, and their elucidation of some points in the history of "craters of elevation."

* Scrope on Volcanos, p. 179.

† Geol. Trans. 2nd ser. vol. ii. p. 345. See also above, vol. i. p. 76, and Sir H. Davy's remarks on the Lake of the Solfatara, Appendix to vol. i. p. 463.

‡ A letter on the formation of Monte Nuovo, by an eye-witness, is still extant: a translation of it, by Mr. Leonard Horner, is published in the Quarterly Journal of the Geological Society of London, vol iii. part 2, *Miscell.*, p. 19.

The Lipari Isles, between Naples and Sicily, lying, as it were, midway between Vesuvius and Etna, present a character very analogous to the district above described. The crater of one of the islands, Stromboli, has been in constant activity from the earliest historical period. It always contains melted lava in constant motion, and at uncertain intervals the molten mass suddenly rises, and large bubbles appear, which, upon reaching to the brim of the crater, explode with a sound resembling thunder, and masses of lava, with dust and smoke, are thrown into the air; the incandescent fluid then sinks down to its former level.*

The cliffs of St. Calogero, which are about two hundred feet high, and extend four or five miles along the coast, consist of horizontal beds of volcanic tuff. From the perennial emanation of sulphurous vapours, the rocks are decomposed; alum, gypsum, and other sulphuric salts are formed, as well as muriate of ammonia and silky crystals of boracic acid. The dark clays have become yellow, white, red, pink, &c., and marked with stripes of various colours, from the gaseous emanations that are constantly issuing from beneath: these mottled clays strikingly resemble in appearance the variegated strata of the Trias (p. 544). Veins of chalcedony and opal occur, and pumice-stone and obsidian are abundant. Dykes and veins of trachyte intersect the tuff in every direction (*Lign.* 197, *fig.* 1), like the intrusions of trap in the ancient sedimentary formations.

6. Ischia and Vesuvius.—The celebrated mountain of Vesuvius is about four thousand feet high, and its crest is now broken and irregular; but when Northern Italy was first colonized by the Greeks, "its cone was of a regular form, with a flattish summit, where the remains of an ancient crater, nearly filled up, had left a slight depression, covered in its interior by wild vines, and with a sterile plain at the bottom." From the earliest period to which tradition refers, to the first century of the Christian era, this mountain was in a dormant state, and the neighbouring isles of Ischia and Procida were the theatres of constant explosions and earthquakes. The early Greek colonists who attempted a settlement were obliged to abandon the territory, in consequence of the frequency and violence of the subterranean movements.

* *Spallanzani*; Scrope "On Volcanos," p. 18.

Ischia.—But subsequently to the great outburst of Vesuvius, Ischia has been almost entirely dormant; and it is therefore inferred that the latter volcano was the vent through which the elastic fluids and incandescent materials of the subterranean fires of Italy escaped before Vesuvius resumed its activity. Ischia has numerous cones; the central one, Epomeo, is 2600 feet high, and has traces of two large craters on its summit. This mountain appears to have been submarine at its origin, but, since its elevation above the sea, other eruptions have burst out at various points; and a lava-stream that issued from its base is still arid, and covered in parts with cinders and scoriæ. The materials erupted by the cones of Ischia are, for the most part, trachytes or felspathic lavas.

Vesuvius.—In the year 63 of the Christian era, Vesuvius exhibited the first symptom of internal change, in an earthquake which occasioned considerable damage to many neighbouring cities, and of whose effects traces may yet be witnessed among the interesting memorials of the awful catastrophe which soon afterwards took place.* After this event, slight shocks of earthquakes were frequent, when on the 24th of August, in the year 79, a tremendous eruption of the long pent-up incandescent materials of the volcano burst forth, and spread destruction over the surrounding country, overwhelming three cities, with many of their inhabitants, and burying all traces of their existence beneath immense accumulations of ashes, sand, and scoriæ. All the fearful circumstances connected with this event, and the attendant physical phenomena, are so well known, that it is unnecessary to dwell upon the subject.

From that period to the present time, the internal fires of Italy have resumed their ancient focus, and Vesuvius, with occasional periods of tranquillity, has been more or less energetic.†

7. STRUCTURE OF VOLCANIC MOUNTAINS.—As the present active volcanos for the most part emit streams of lava, showers of ashes, cinders, and scoriæ, and floods of mud or tuff, their cones consist of erupted materials disposed more or less concentrically; and where sections are exposed, the beds have what is called a *quâ-quâ-versal* dip; that is, they regularly incline on every side of the mountain. These are termed *Craters of Eruption;* they consist of successive strata

* Daubeny on Volcanos, 2nd edit. p. 220.

† For a sketch of the history of Vesuvius, see Scrope, Quart. Journ. Geol. Soc. vol. xii. p. 337.

of volcanic matter poured out from a fissure or vent, communicating with the deep-seated focus of igneous action.

The central crater of another class of volcanic mountains is formed of preëxisting horizontal rocks and strata, that have been forced into highly inclined positions by a sudden and violent upburst of incandescent mineral matter, or by the expansion of elastic vapours. A dome or cone is thus produced, with a central opening, around which the uplifted strata are concentrically arranged; being covered to a greater or less extent by the materials poured out by subsequent eruptions. These have been termed *Craters of Elevation*, by Von Buch. The structure of such volcanic mountains will be readily understood by referring to the sections of the Wren's Nest (p. 811), and of Crich Hill, near Matlock (p. 699), both of which are examples of originally horizontal strata elevated into a dome by a protrusion of volcanic matter. If in either of these instances the upheaving force had been sufficient to propel the trap through the middle of the dome, a crater of elevation would have been formed, through which the igneous matter would have escaped. It is by a movement of this kind, as we have already had occasion to explain, that valleys of elevation have been produced (p. 818).

From Mr. Scrope's observations * on the structure of Vesuvius we obtain the following general sketch of the character of Vesuvius and of its older form, as Somma; and this will serve to explain the formation of craters of eruption:—

Vesuvius is an exceedingly regular mountain on a small scale. All the visible lavas, and the greater part of the conglomerates, are basaltic; and, owing to the great fluidity of lavas of this mineral character, they have, when produced from the common vent, taken their course in spreading sheets down the outer slope of the mountain; while the scoriæ and fragmentary substances, projected at the same time into the air, were

* *Geol. Trans.* 2nd ser. vol. ii. p. 338.

spread pretty evenly over them; so that the result of successive eruptions of this kind has been the formation of a regularly conical mountain, with a gradually diminishing slope on all sides, from the central heights to the plain around; exhibiting in the ravines that furrow its sides, as well as in the abrupt sections afforded by the walls of the great crater, its composition of repeatedly alternating beds of basalt and basaltic conglomerates, more or less irregular in thickness, but dipping uniformly on all sides away from the vent, with an inclination corresponding exactly to the external slopes of the mountain.

The eruptions of Vesuvius seem very rarely to have taken place from any other than the central vent; a few small cones immediately above Torre del Greco, thrown up in 1794, and the cone on which the Camaldoli della Torre is built, are the only indications of explosions having burst from the sides of the mountain. The vast number of vertical basaltic dykes which intersect the horizontal beds observable in the broken cliffs of the old crater (Atrio del Cavallo) bear witness, however, that the lava was not so frequently elevated to the summit of the mountain, without occasioning numberless cracks and rents in its internal structure. There is great reason to conclude that the old crater of Somma, whose steep walls now half encircle the cone of Vesuvius, was formed by the celebrated eruption of the year 79, which occasioned the death of the elder Pliny, and buried Herculaneum, Pompeii, and Stabiæ beneath a bed of ashes and fragmentary scoriæ, &c., from thirty to one hundred feet in thickness.

8. VOLCANIC PRODUCTS.*—Before we pass to the consideration of the phenomena attendant on a volcanic eruption, we will examine some of the principal minerals which enter into the composition of the lavas and other substances ejected from volcanos.

Lava is a term applied to any mineral matter, liquefied by heat, that has issued in a stream or current from a volcanic aperture: when consolidated by cooling, it may consist either of scoriæ, pumice, obsidian, trachyte, basalt, &c., according to its mineral composition, and its slow or rapid refrigeration. The greater or less degree of pressure under which the solidification either of liquid or merely softened mineral substances takes place—as, for example, in the open air, or at the bottom of the sea, or in deep-seated subterranean cavities—appears to be the prin-

* See Lyell's "Manual," chap. 28.

cipal cause of the difference between the ancient plutonic and the modern volcanic rocks.*

Among the products of modern volcanos five of the metals occur; namely, iron, copper, lead, arsenic, and titanium; besides selenium, boron, &c. The number of simple minerals found in the rocks of Vesuvius amounts to at least 400 species; and many of them are of great beauty. Specular iron is common in the cavities of the hard lavas. In some of the ancient Vesuvian lavas there are decided indications of a concretional and prismatic structure, and a tendency to divide into columns, like the basaltic rocks.

Aqueous vapours are emitted in abundance from volcanos, and often from their condensation give rise to copious springs. The gaseous emanations from the fumaroles, or lesser vents, frequently contain chlorides of lead, iron, copper, ammonia, soda, &c.

The lofty volcanic peaks which reach far above the limits of perpetual snow, as those of the Andes (*Cotopaxi*, which is 19,070 feet high), are frequently the cause of frightful inundations from the sudden melting of the snow, occasioned by the evolution of heat during an eruption. Torrents of water, bearing along both heated masses of scoriæ and blocks of ice, rush down the sides of the mountains, and overwhelm the plains below. Water from the melted snow is also continually finding its way into the hollows and fissures of the trachytic rocks, and vast subterranean lakes are thus formed in the interior of the volcanic mass: and when these reservoirs are burst open by the earthquakes that precede eruptions, water and tufaceous mud, not unfrequently accompanied with swarms of fishes that inhabited the internal pools, are ejected with great violence.

The chief constituents of lavas are the substances termed *felspar* and *augite*, and the lavas are classed according as either of these ingredients predominates. When the felspar prevails, the mass is called *Trachyte*, which is generally of a coarse grain, with a harshness of texture, and a considerable degree of porosity; when the grain is fine and compact, but irregular, it constitutes *Trachytic porphyry;* when the particles are so fused as to have a resinous or glassy texture, it forms *Pitchstone* and *Obsidian*. If *augite* constitute a large proportion of a rock, it is termed *Basalt; Dolerite* is another rock of the same class.

The lavas ejected from Vesuvius present considerable variety of appearance and composition: they occur in the state of pumice-stone,—vesicular scoriæ, that is, cinders full of hollow cells,—and compact heavy masses of molten rock, which are sometimes spotted internally with red, yellow, and grey. Mica occurs plentifully in some recent trachytes, but crystallized quartz and hornblende, so abundant in granite, are extremely

* Humboldt.

rare. Pumice is supposed to be produced by a considerable disengagement of vapour having taken place while the lava was in a plastic, but not entirely in a fluid state; the escape of the gaseous matter giving rise to the porous structure of this mineral. Dolomieu observes, that one kind of pumice seems to be derived from the fusion of granite, since it contains fragments of quartz, mica, and felspar, and that, when such fragments were exposed to heat, they were converted into a substance resembling the surrounding pumice.

9. LAVA-CURRENTS, DYKES, AND VEINS.*—As the aspect and nature of lava-currents will be easily comprehended by the descriptions of volcanic eruptions which I shall presently place before you, it will suffice to mention in this place, that the appearance of lava in motion is that of a sluggish viscid stream loaded with red-hot cinders, ashes, and detached fragments of rocks, rolling one over the other, and producing a loud crackling noise.

Captain Basil Hall aptly compares the movements of a lava-current to that of a glacier :—"They are both," he observes, "more or less, frozen or half-congealed rivers; they both obey the law of gravitation with great reluctance, being essentially so sluggish, that, although they move along the bottoms of valleys with a force well-nigh irresistible, yet their motion is sometimes scarcely perceptible. Both glaciers and lava-streams, by occasionally acting the part of huge dams across valleys and ravines, cause immense accumulations of water; it is true these barriers are more fragile in the case of glaciers, and the consequences are therefore the more destructive." †

The effects produced by lava-currents, and their rate of progress, depend of course on their degree of incandescence and fluidity. When the molten mass first issues, it appears like a stream of fire, but the surface quickly acquires a rough scum, or crust, which soon thickens, and is broken into angular pieces by the onward motion of the fluid beneath. In this condition it appears like melted iron or copper; and, if a stick be thrust in, large semifluid masses adhere, and may be removed; and coins or other articles may be plunged in, and will remain permanently imbedded when the lava cools. ‡

Lava-currents from Vesuvius have flowed a mile and a half in fourteen

* *See* Lyell's "Manual," chapter 29, for details and illustrations.

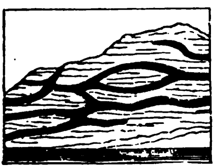
† "Patchwork," by Captain Basil Hall, vol. iii. p. 153.

‡ Persons visiting Vesuvius generally bring away such momentos of ascent to its crater.

minutes; others have reached the sea in three hours from the summit of the mountain, a distance of 3200 yards. The stream which destroyed Catania, in 1669, was fourteen miles long and five wide. In Etna, currents have been traced forty miles in length; and a stream that issued from Mount Hecla, in Iceland, is computed at ninety-four miles in length, and fifty in its greatest breadth; and its depth, where there were obstacles to its progress, was in some places several hundred feet.

Lava-currents retain a high temperature for a long period; some have been observed to flow slowly ten years after their eruption. A mass of lava on the flanks of Vesuvius ignited wood thrust into it four years after its motion had ceased.

The cooled lavas and other mineral products which form the great mass of a volcanic mountain are rent and torn by the earthquakes which generally precede every fresh eruption; and these fissures and chasms become filled by subsequent injections of molten rock. In this manner dykes and veins are formed in the trachytic and scoriaceous masses of Vesuvius, Etna, and other active volcanos (*Lign.* 198), resembling on a small scale the intrusive trap-dykes in the ancient strata, of which we have already noticed many examples.



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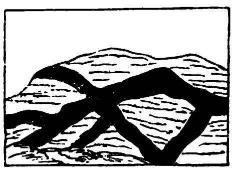

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LIGN. 198.—DYKES AND VEINS IN LAVA.

Fig. 1. Veins and dykes of slaggy lava in volcanic tuff; Stromboli.
— 2. Lava-dykes in scoriæ and sand; Etna.

The loose sand, scoriæ, and ashes which have been either wafted by the winds and fallen into the sea, or washed down by torrents on the plains, become agglutinated together and form an earthy conglomerate, which is termed *volcanic tuff*. This substance is frequently traversed by veins and dykes of lava, thrown up by subsequent eruptions. It often happens that the beds thus permeated, being formed of materials that readily decompose, are partially or wholly worn away, while the durable intruded dykes remain, and stand out in relief, sometimes forming vertical walls or buttresses, of great thickness and extent; of which the celebrated Val del Bove, of Etna, to be noticed in the sequel, affords some of the most remarkable examples.

10. ERUPTIONS OF VESUVIUS.—In the early periods of activity, violent gaseous explosions, with showers of scoriæ, ashes, and sand, characterized the eruptions of Vesuvius;* but since the existence of the present crater lava-currents have generally been ejected. The appearance of an ordinary eruption, seen by night, has been thus picturesquely described by a traveller:—

"It was about half-past ten when we reached the foot of the craters, which were both tremendously agitated; the great vent threw up immense columns of fire, mingled with the blackest smoke and sand. Each explosion was preceded by a bellowing noise, like thunder, in the interior of the mountain. The smaller vent was the most active; and the explosions followed each other so rapidly that we could not count three seconds between them. The stones which were emitted were fourteen seconds in falling back to the crater; consequently, there were always the discharge of five or six explosions—sometimes more than twenty—in the air at once. These stones were thrown up perpendicularly, in the shape of a wide-spreading sheaf, producing the most magnificent effect imaginable. The smallest stones appeared to be of the size of cannon-balls; the greater were like bomb-shells; but others were pieces of rock, five or six cubic feet in size, and some of the most enormous dimensions: the latter generally fell on the ridge of the crater, and rolled down its sides, splitting into fragments as they struck against the hard and cutting masses of cold lava. The smoke emitted by the smaller cone was white, and its appearance inconceivably grand and beautiful; but the other crater, though

* The craters of Auvergne, (vol. i. p. 272), that exhibit no traces of lava-currents, are also supposed to have been produced by explosions.

less active, was much more terrible; and the thick blackness of its gigantic volumes of smoke partly concealed the fire which it vomited. Both vents occasionally burst forth at the same instant, and with the most tremendous fury, the ejected stones intermingling in the air.

"If any person could accurately fancy the effect of 500,000 sky-rockets darting up at once to a height of three or four thousand feet, and then falling back in the shape of red-hot balls, shells, and large rocks of fire, he might have an idea of a single explosion of this burning mountain; but it is doubtful whether any imagination can conceive the effect of one hundred of such explosions in the space of five minutes, or of twelve hundred or more in the course of an hour, as we saw them! Yet this was only a part of the sublime spectacle before us.

"On emerging from the darkness, occasioned by the smaller crater being hidden by the large one, as we passed round to the other side of the mountain, we found the whole scene illuminated by the river of lava, which gushed out of the valley formed by the craters and the hill on which we now stood. The fiery current was narrow at its source, apparently not more than a few feet in breadth; but it quickly widened, and soon divided into two streams, one of which was at least forty feet wide, and the other somewhat less: between them was a sort of island, below which they reunited into one broad river, that was at length lost sight of in the deep windings and ravines of the mountain." *

In an eruption witnessed by Sir W. Hamilton, jets of liquid lava, mingled with stones and scoriæ, were thrown up to a height of ten thousand feet.

The streams of lava, which issue with great velocity, are in a state of perfect fusion; but as they cool on the surface, they crack, and the matter becomes vesicular or porous; at a considerable distance from their source, they resemble a

* *From* the Saturday Magazine.

heap of scoriæ, or cinders, from an iron-foundry, rolling slowly along, and falling, with a rattling noise, one over the other.

The eruptions of Vesuvius, its cones and craters, and the still older and partly encircling crater of Somma, have afforded continuous and important lessons to geologists as to the mode of action and nature of volcanic forces. In 1856, Mr. Poulett Scrope read before the Geological Society a very interesting and instructive résumé of his views on the mode of production of volcanic craters, and on the nature of the liquidity of lavas, mainly illustrated by the Vesuvian phenomena, and originally advanced in his work on Volcanos in 1824. In the Memoir referred to, the first point insisted on is the formation of all volcanic cones and craters by the simple process observed in habitually active volcanos, namely, the eruptive ejection of lavas and fragmentary matter from a volcanic vent; the accumulation of which around it cannot fail to give rise to the cone-shaped mountain so characteristic of a volcano, and to the crater usually contained in it. The author showed, by the history of Vesuvius, that the cone of that mountain has, within the last hundred years, been at least five several times emptied by explosions of a paroxysmal character, and as often refilled by the products of subsequent minor eruptions; while throughout this time the exterior of the cone has been gradually increasing in bulk, and the old crater of Somma as gradually being filled up, by accretions from the volcanic matter ejected beyond the lip of the Vesuvian crater. He refuses to believe that any other process originally formed the outer cone and crater of Somma, than that which he and others have seen to be continually augmenting the inner cone of Vesuvius, and which before his eyes in 1822 scooped out of its heart a crater concentric to that of Somma, three miles in circumference, and some 2000 feet in depth. And generally of other great craters, ancient or modern, such as Palma, Santorini, the Val del Bove, &c., he considers, that no argument in favour of their having any other than a similarly "eruptive" origin can be derived from the fact of their dimensions exceeding those of the crater of Vesuvius. The authentic accounts of enormous quantities of ejected pumice, scoriæ, or ashes thrown out by many eruptions from Polynesian or American volcanos, reaching to distances of above a thousand miles, and of course spreading over the whole intermediate space, to a thickness sometimes of 10 or 12 feet at more than twenty-five miles from the volcano, would amply account for the dispersion, by explosive eruptions, of the contents of the largest craters ever observed.

At the same time the author guards himself from being supposed to have ever denied that some amount of elevation has taken place in the external cone of a volcano through the occasional injection of lava from within into rents broken across its framework, and hardened into dykes, which may be called a process of gradual distension. This, in fact, was suggested by him in 1824. All he contends against is the theory of Von Buch, that volcanic mountains are the result of the elevation of nearly horizontal beds of lava and conglomerates by some sudden expansion. He maintains, on the contrary, that the growth of a volcano by accretion, through eruptive ejections on the exterior, and partial distension from within, is a gradual, though intermittent, normal process, which may be watched almost like the growth of a tree.

The author next referred to the opinion published by him in 1824, that the liquidity of the stony and crystalline lavas (excluding the vitreous varieties) at the time of their protrusion is owing, not to complete fusion, but to the entanglement between their component granular or crystalline particles of some fluid, chiefly water, at an intense heat, of course, but unvaporized by reason of the extreme pressure to which they are subjected while beneath the earth, and escaping in vast bubbles of steam, when, by the opening of a fissure of escape, its discharge is permitted, and also by a kind of exudation through the pores and crevices of the expelled lavas as they cool.

The author originally extended this theory of the combination of aqueous with igneous agency in lavas to all the crystalline plutonic rocks, which he considered to be derived from a mass existing beneath the crust of the globe under the above circumstances, in a state of extreme tension, such as on the occurrence of any sufficient local relaxation of the restraining pressure from above, or increase of temperature from within, must occasion its partial intumescence, and the consequent fracture and elevation of the overlying rocks, with or without extravasations of the intumescent crystalline matter through rents, in the form either of volcanic eruptions, or the protrusion of the granitoidal axes of mountain-chains.

These ideas on the character of the liquidity of lavas and the hypogene crystalline rocks, promulgated by the author in 1824—1826, were considered unchemical at that time, and little regarded. They have, however, of late been reproduced by M. Scheerer of Christiania, and adopted by M. Elie de Beaumont, and have received much confirmation from recent researches into the conduct of water under pressure at high temperatures, its power of taking silex into solution, &c.

The author further asks the attention of geologists to the ideas developed by him in the same early work, and founded on actual and careful observations, as to the change of position occasioned in the *component crystals of* a matter moving in the pasty state here attributed to lavas and other plutonic rocks, during their emission or elevation under extreme pressure. He produced examples from the ribboned trachytes and pearlstones of Italy, Hungary, and Mexico. He considers gneiss to be granite elongated by a powerful lateral squeeze, probably at the time of its expulsion; and mica-schist to be the extreme result of the same action upon the lateral bands or selvages of the extruded mass or great dyke. This he thinks a more probable origin than the usual metamorphic theory of the melting and reconsolidation of sedimentary strata, though the one does not wholly exclude the other. At all events he considers the evidence presented in the peculiarities of texture, structure, and position of the laminated crystalline rocks to be conclusive as to their having been squeezed, flattened, and drawn out in the direction of their upcast, and attributes this process to the same elevatory movements which have thrust them up, and often forced them into wrinkled foldings on the grandest as well as on the most minute scale. To this same reärrangement of their crystalline plates or flakes under pressure he attributes also their lamellar cleavage. He refers to Mr. Sorby's recent papers and experiments on slaty cleavage as confirming these views. The paper ends by recommending the more earnest study of the dynamics of geology, which have in this country been perhaps of late years somewhat neglected.

11. Herculaneum and Pompeii.—We have above described the phenomena attendant on the modern paroxysms of Vesuvius: but this celebrated mountain is invested with surpassing interest, from the wonderful preservation of the cities, which were overwhelmed by its first-recorded eruption, in the seventy-ninth year of the Christian era.

In the words of an eloquent writer, "After nearly seventeen centuries had rolled away, the city of Pompeii was disinterred from its silent tomb,—all vivid with undimmed hues,—its walls fresh, as if painted yesterday,—not a tint faded on the rich mosaic of its floors,—in its Forum the half-finished columns, as left by the workman's hand,—before the trees in its gardens the sacrificial tripod,—in its halls the chest of treasure,—in its baths the strigil,—in its theatres he counter of admission,—in its saloons the furniture and e lamp,—in its triclinia the fragments of the last feast,—

in its cubicula the perfumes and the rouge of faded beauty, —and everywhere, the skeletons of those who once moved the springs of that minute yet gorgeous machine of luxury and of life." *

From the description of the catastrophe by an eye-witness, it appears that this outburst of Vesuvius was marked by a terrific eruption of ashes and scoriæ, which, borne upwards by vapours, rose in an immense column, and is described by the younger Pliny, in his letter to Tacitus, as resembling a lofty pine spreading out at its summit into wide shadowing branches: † and then followed total darkness, occasioned by the descent of this overwhelming cloud of volcanic matter, which completed the destruction of the devoted cities, and buried Herculaneum, Pompeii, and Stabiæ beneath an accumulation of ashes, cinders, and scoriæ, to a depth of from sixty to one hundred and twenty feet.

No traces have been perceived of lava-currents or of melted matter; the various utensils and works of art, as you may observe in the Pompeiian lamps, vases, beads, and

* Sir E. Bulwer Lytton's "Last Days of Pompeii."

† The elder Pliny, who, at the time of this outburst of Vesuvius, held the command of the Roman fleet, stationed at Misenum—a cape or headland about twice the distance westward from the volcano as the city of Naples,—in his anxiety to obtain a nearer view of the phenomenon, fell a victim to the sulphurous vapours: and his nephew, the younger Pliny, who remained with the fleet at Misenum, has left a graphic description of the awful scene in his letters to Tacitus. He states, that a dense column of vapour was first seen arising vertically from Vesuvius, and which spread itself out laterally, so as to resemble the head and trunk of the Italian pine-tree. This black cloud was occasionally pierced by flashes of fire as vivid as lightning, and the whole atmosphere suddenly became darker than night. The eruption burst forth with such amazing force, that ashes fell even upon the ships at Misenum, and in such quantities as to cause a shoal in one part of the neighbouring sea. In the mean time, the ground rocked terribly; and the sea receded so far from the shore, that many marine animals were left exposed on the dry sand.

instruments in the British Museum, exhibit no appearance of having been exposed to the action of fire. Even the delicate papyri appear to have sustained more injury from the effects of moisture and exposure to the air, than from heat; for they contain matter soluble in naphtha, and are in fact

LIGN. 109.—VIEW OF VESUVIUS, LOOKING OVER THE PLAIN AND CITY OF POMPEII.

The site of *Pompeii* is marked by the long line of embankments in the middle distance, formed by the ashes thrown out of the excavations. The River *Sarnus* is seen on the left.

(From Sir W. Gell's Pompeiana.)

peat in which bituminization has commenced.* In Pompeii, the sand and stones are loose and unconsolidated; but in Herculaneum, the houses and works of art are imbedded in solid tuff, which must have originated either from a torrent of mud, or from ashes moistened by water. Hence statues are found unchanged, although surrounded by hard tuff, bearing the impressions of the minutest lines. The beams of the houses have undergone but little alteration, except that they are invested with a black crust. Linen and fishing-nets, loaves of bread with the impress of the baker's name;

* Dr. Macculloch.

even fruits, as walnuts, almonds, and chestnuts, are still distinctly recognisable. The remarkable preservation, for nearly two thousand years, of whole cities, with their houses, furniture, and the most perishable substances, imbedded in volcanic matter, may be compared to those geological events by which the forests of an earlier world, and the remains of the colossal dragon-forms which inhabited the ancient lands and waters, have been accumulated beneath the deposits of innumerable ages.

12. CONSERVATIVE EFFECTS OF LAVA-CURRENTS.—Although no vestiges of animals or plants are likely to be found in volcanic products that have been in an incandescent state, yet so slow is the conducting power of many earths, that beds of shells and vegetable remains may be overflowed by streams of molten lava without injury, if protected by even a thin covering of sand or other non-conducting material. In like manner the ancient basaltic lavas have burst through and overwhelmed sedimentary strata, and yet the most delicate animal and vegetable substances remain uninjured; transmuted, indeed, into stone, but still retaining their original structure. Thus, in the eocene (?) beds of Glarus, although the rock has been converted into slate by intense heat, yet the fishes remain (p. 366); the strata of Monte Bolca, though capped with basalt, yet swarm with ichthyolites (p. 269); the fiery currents of Auvergne have flowed over the lacustrine limestones, and still vestiges of insects, serpents, and quadrupeds are preserved (p. 277); the tertiary forests of the Andes, which grew on beds of lava, now lie buried beneath subsequent volcanic eruptions of prodigious thickness (p. 289); and bones either of the Dodo or of the Solitaire are found imbedded in sandstone covered by lava of recent origin (p. 130).

A very remarkable circumstance is mentioned by Sir. C. Lyell,—the preservation of a bed of ice, beneath a stream of incandescent lava. The intense heat experienced in the south of Europe during the summer and autumn of 1828 caused the usual supplies of ice entirely to fail. Great distress was consequently felt from the want of a commodity regarded in those countries rather as an article of necessity than of luxury. Etna was, therefore, carefully explored, in the hope of discovering some crevice or natural grotto on the mountain where drifted snow was still preserved. Nor was the search unsuccessful; for a small mass of perennial ice at the foot of the highest cone was found to be part of a large continuous glacier covered by a sheet of lava. The ice was quarried, and the superposition of the lava ascertained to continue for several hundred yards; unfortunately, the ice was so extremely hard, and the removal of it so expensive, that there is no probability of the operations being renewed.* Sir C. Lyell explains this apparently paradoxical fact by supposing that a deep mass of drift-snow was covered by a layer of volcanic sand, which is an extremely bad conducter of heat; and thus the subsequent liquid lava might have flowed over the whole without affecting the ice beneath, which at such a height (ten thousand feet above the level of the sea) would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from below.

13. Organic Remains in Lava.—The silicious shields or frustules of Infusoria are often found as a component part of volcanic ash and tuff, both of ancient and modern origin,† and were probably derived from the subterranean pools or lakes; as in the case of the showers of fishes which occasionally descend during a volcanic eruption.‡ Infusorial

* Principles of Geology, vol. ii. pp. 124—126, 9th edit. p. 412.

† Prof. Ehrenberg has published several notices of this phenomenon in the Journal and Transactions of the Berlin Academy of Sciences; and complete illustrations are given in his magnificent "Mikrogeologie," fol. 1855.

‡ Humboldt's Cosmos, vol. i. p. 230. A putrid fever which prevailed in 1691, in Ibarra, north of Quito, was ascribed to the decomposition of the quantity of dead fish ejected from the volcano of Imbaburu.

remains are not uncommon in the volcanic dust that falls on vessels, often hundreds of miles from land. An ancient bed of tuff in Oregon is full of infusorial remains.*

In the tuff of Vesuvius, I have seen the impressions of dicotyledonous leaves; and charred wood is occasionally met with in the scoriæ of Herculaneum.

A curious circumstance occasionally results from the invasion of a grove or forest by a stream of lava. The trunks of the trees, at their base, become enveloped by the molten mass, but the upper part and the branches are set on fire, and burn down to the surface of the lava. The trunks surrounded by the lava are only charred, and if, as often happens, this carbonaceous matter is afterwards washed away, or otherwise removed, hollow cylindrical tubes, having their sides marked with the imprint of the bark of the trunks, remain in the solid rock. Such moulds are not uncommon in the Isle of Bourbon, in those lava-currents that have extended their ravages through the palm-forests.

A remarkable fact, arising from a similar cause, is mentioned by Count Strzelecki, as having come under his notice in the valley of the Derwent in Van Diemen's Land. Opalized coniferous wood is abundant, and in some parts the truncated stumps are imbedded in porous and scoriaceous basalt and trachytic conglomerate; and in many instances the basalt contains hollows, which are the moulds of trees that have been consumed. It appears that the stems which had been silicified withstood the intensity of the incandescent lava; while other trees, placed in circumstances unfavourable to their previous petrifaction, were charred, but not destroyed; for, having been either green, or saturated with water, they resisted the progress of combustion, so as to leave by their subsequent decomposition cylindrical upright cavities in the basaltic scoriæ, with impressions similar to the rugged bark of a carbonized tree. Into some of these

* Dr. Bailey.

hollows a second eruption of lava has formed casts of the consumed trunks in basalt.*

14. MOUNT ETNA.—This volcanic cone, which is situated in the Island of Sicily, and is entirely composed of erupted mineral substances, rises majestically to the height of upwards of two miles (or 10,872 feet), the circumference of its base exceeding 180 miles: on a clear day it may be distinctly seen from Malta, a distance of 150 miles. Compared with this prodigious mass of igneous products, Vesuvius sinks into insignificance; for, while the lava-streams of the latter do not exceed seven miles, those of Etna are often from fifteen to thirty miles in length, and five miles in breadth, and from fifty to one hundred feet in thickness.† The surface of Etna presents three distinct regions: around the base for an extent of twelve miles, the country is richly cultivated, and abounds in vineyards and pastures, and is the site of many towns, monasteries, and villages. The middle or temperate zone above, is covered with forests of oak and chestnut, and a luxuriant vegetation reaches to within a mile of the summit. Above this all is sterility and desolation, and the highest point of the mountain is covered with eternal snow. The crater is about a quarter of a mile in height, and three quarters of a mile in circumference, and is situated in the centre of a gently inclined plain, three miles in diameter. From the crater a column of vapour constantly issues, emanating from the mass of incandescent mineral matter which fills up the interior, and may be seen, in a state of ebullition, in the fumaroles or chasms in some of the lateral crevices, of which there are generally several accessible.

Etna is recorded as having been in a state of activity before the Trojan war; and ever since, at varying intervals, violent eruptions have occurred. In an eruption in 1669,

* Physical Description of New South Wales.

† Dr. Daubeny on Volcanos.

the torrent of lava inundated a space of fourteen miles in length, and four in breadth; burying beneath it 5000 villas and other habitations, with part of the city of Catania, and at length falling into the sea: during several months before the lava burst out, the old mouth, or great crater, was observed to send forth more smoke and flame than usual, and the top fell in; so that the cone became much lowered.

In 1809, twelve new craters opened, about half-way down the mountain, and threw out rivers of burning lava, by which several estates and farms were covered to the depth of thirty or forty feet: and in 1811, other vents appeared on the eastern side; and discharged torrents of liquid lava with amazing force.

In 1832, a violent paroxysm took place, and continued with but little intermission for several weeks. "On the 31st of October, in the middle of the night, there arose, without any previous indication, a column of smoke and flame from the base of the large cone, on the northern side; and, shortly after, an immense quantity of fluid matter was discharged from the crater, on the western side, and divided into numerous streams. Next morning, repeated earthquakes, the increased noise of the lava, which now flowed rapidly, and the immense volumes of thick black smoke at the foot of Monte Scavo, announced that the eruption had greatly increased in violence, and several streams of lava were seen descending. On the 2nd of November, contrary to all expectation, the eruption ceased, and the lava was found to be so far cooled, that several adventurous observers were enabled to get upon it, and walk a few paces. On the 3rd, the hope that the fire was almost extinct was nearly certain; but, in the evening, a violent earthquake, followed by several smaller ones, with a fresh quantity of smoke, foretold a fresh eruption; and two hours before midnight, another severe shock occurred, and was succeeded by black smoke mingled with flames, and incessant thunder.

"Having approached," says Signor di Luca, "as nearly as was prudent to the hollow from which the fire issued, we found four apertures, which threw out burning matter. Raising our eyes from these vents, we observed a cleft or rent, about a mile in length, from which volumes of smoke arose from time to time; and, as at the bottom it reached the openings above mentioned, it enabled us to behold the burning furnace in the interior of the mountain. Meanwhile, the thunder was incessant, and the detonations were terrible; the lava continued to flow; and enormous masses of red-hot substances were thrown to a great height, mingled with vast volumes of flame and smoke. The shocks of earthquake were likewise so violent, that horses, and other animals, fled in terror from the places where they were feeding."

15. THE VAL DEL BOVE.—But by far the most interesting feature of Etna is an immense depression or excavation on the eastern side of the mountain, called the *Val del Bove*. This vast plain, or rather circular hollow, is five miles in diameter, and from two to three thousand feet in the height of its bounding precipices, which in most places are nearly perpendicular. This remarkable area, according to some observers, has resulted from the giving way and subsidence of part of the crust of the volcano, from some violent action in the interior, which occasioned the sudden removal of an enormous mass of mineral matter.* This plain is encircled by subordinate volcanic mountains, some of which are co-

* Sudden depressions of the surface of the land are not unfrequent concomitants of subterranean movements, and occasionally produce the most frightful catastrophes. In 1772, Papandayang, one of the largest volcanos in the Island of Java, suddenly sunk down with a terrific noise, and an area fifteen miles long and six wide was swallowed up; many hundred persons and forty villages were destroyed, being either ingulfed with the sunken mass, or overwhelmed by the volcanic matter that issued forth, and spread over the surrounding country to a considerable distance. The original mountain was diminished 4000 feet in height.

vered by forests, while others are bare and arid, like many of the cones of Auvergne. The walls or cliffs surrounding this depression are formed of successive layers of lava of variable thickness, with interposed beds of tuff, ashes, and igneous conglomerates of different colours and degrees of fineness. They slope downwards towards the sea at an angle of from twenty to thirty degrees, and have evidently been formed at various intervals by successive eruptions from the top of the mountain, and were continuous before the subsidence took place which gave this region its present character.

Mr. Scrope,* however, argues that the evidence advanced for this view of the case is not conclusive, and that the whole of the wanting mass of materials in this hollow on the side of Etna may have been blown away, just as "entire mountains, of a magnitude far exceeding that of Vesuvius and Somma itself," have been blown into the air by eruptive violence.

The perpendicular sides of this natural amphitheatre are everywhere marked by vertical walls or dykes, which not only intersect the concentric sheets of lava and tuff, but standing out in bold relief, like prodigious buttresses, impart a most extraordinary character to the scene; the greater induration of these intruded dykes having enabled them to resist the denuding action which has removed the less coherent preëxisting erupted materials.† These buttresses are from two to twenty feet in thickness, and, being of immense height, are extremely picturesque; some of them are composed of trachyte, and others of blue compact basalt with olivine. The surface of the plain is wild and desolate in the extreme, presenting the appearance of a tempestuous sea of liquid lava, suddenly congealed. Innumerable currents of lava are seen piled one upon the other; some of which terminate abruptly, while others have extended across

* Quart. Journ. Geol. Soc. vol. xii. p. 330. † See above, p. 852.

the Val, and descended in cascades into the lower fertile regions, where they are spread out in sterile tracts amid the vineyards and orange-groves.*

The varied and picturesque scenery of Etna, the phenomena of volcanic action which are there so strikingly exhibited, as well as those which have taken place in periods long antecedent to human history and tradition, but of which the natural records remain, are described by Sir C. Lyell with that vigour and fidelity which characterize all the productions of his pen; and his works should be consulted by those who desire fully to comprehend the nature of some of the most interesting physical changes which are in progress on the surface of our planet.†

16. VOLCANO OF KILAUEA.—Of the existing volcanos, those of Kilauea and Mauna Loa, in Hawaii,‡ exhibit volcanic action in its most sublime and imposing aspect. The island of Hawaii, which is about seventy miles long, and covers an area of 4000 square miles, is a complete mass of volcanic matter, perforated by innumerable craters. It is in fact a hollow cone, rising to an altitude of 16,000 feet, having numerous vents over a vast incandescent mass, which doubtless extends beneath the bed of the ocean; the island forming a pyramidal funnel from the furnace beneath, to the atmosphere. Mauna Loa (*great* or *long mountain*) is the apex, and bears an enormous crater. Indeed Kilauea, or Kirauea, is but a lateral crater to Mauna Loa. The following account of a visit to the latter crater, by Mr. Ellis, affords a striking picture of the splendid but awful spectacle which this volcano at the time presented.

* See Captain Basil Hall's interesting description of a visit to the Val del Bove, "Patchwork," vol. iii. p. 31.

† "Principles of Geology," chap. xxvi. See also Daubeny's "Volcanos," 2nd edit. chap. 15.

‡ Hawaii, one of the Sandwich Islands, is well known, under the name Owhyhee, as the scene of the murder of Captain Cook.

"After travelling over extensive plains and climbing rugged steeps, all bearing testimony of igneous origin, the crater of Kilauea suddenly burst upon our view. We found ourselves on the edge of a steep precipice, with a vast plain before us, fifteen or sixteen miles in circumference, and sunk from two hundred to four hundred feet below its

LIGN. 200.—THE VOLCANO OF KILAUEA IN HAWAII.

(From Ellis's Polynesian Researches.)

original level. The surface of this plain was uneven, and strewed over with large stones and volcanic rocks; and in the centre of it was the great crater, at the distance of a mile and a half from the precipice on which we were standing. We proceeded to the northern end of the ridge, where, the sides being less steep, a descent to the plain below seemed practicable; but it required the greatest caution, as the stones and fragments of rock frequently gave way under our feet, and rolled down from above. The steep which we had descended was formed of volcanic matter, apparently of light-red and grey vesicular lava, lying in horizontal beds, varying in thickness from one to forty feet. In a few places the different masses were rent in perpendicular and oblique directions, from top to bottom, either by earthquakes, or by other violent convulsions of the ground. After walking some distance over the plain, which in several places sounded hollow beneath our feet, we came to the edge of the great crater. Before us yawned an immense gulf in the form of a crescent, about two miles in length from north-east to south-west, one mile in width, and 800 feet deep. The bottom was covered with lava, and the south-west and northern parts were one vast flood of burning matter. Fifty-one conical islands of varied form and size, containing as many craters, rose either round the edge or from the surface of the burning lake. Twenty-two constantly emitted either columns of grey smoke or pyramids of brilliant flame: and at the same time vomited from their ignited mouths streams of lava, which rolled in blazing torrents down their black indented sides into the boiling mass below (see *Lign.* 200). The existence of these conical craters led us to conclude, that the boiling cauldron of lava did not form the focus of the volcano, but that this liquid mass was comparatively shallow, and that the basin which contained it was separated by a stratum of solid matter from the great volcanic abyss, which constantly poured out its melted contents through these numerous craters into this upper reservoir. We were further inclined to this opinion from the vast columns of vapour continually ascending from the chasms in the vicinity of the sulphur-banks and pools of water; for they must have been produced by other fire than that which caused the ebullition in the lava at the bottom of the great crater; and also by noticing a number of small vents in vigorous action high up the sides of the great gulf, and apparently quite detached from it. The streams of lava which they emitted rolled down into the lake, and mingled with the melted mass, which, though thrown up by different apertures, had perhaps been originally fused in one vast furnace. The sides of the gulf before us, although composed of different beds of ancient lava, were perpendicular for about 400 feet, and rose from a wide horizontal ledge of solid black lava, of irregular width, but extending completely round. Beneath this ledge the sides sloped gradually towards the burning lake, which was, as nearly as we could judge, three or four hundred feet lower. It was evident that the large crater had been recently filled with liquid lava up to this ledge, and had, by some subterranean channel, emptied itself into the sea, or upon the low land on the shore; and in all probability, this evacuation had caused the inundation of the Kapapala coast, which took place, as we afterwards learned, about three weeks prior to our visit. The grey and in some places apparently calcined sides of the great crater before us—the fissures which intersected the surface of the plain on which we were standing—the long banks of sulphur on the opposite sides of the abyss—the vigorous action of the numerous small craters on its borders—the dense columns of vapour and smoke that rose out of it, at the north and south ends of the plain, together with the ridge of steep rocks by which it was surrounded, rising three or four hundred feet in perpendicular height—

presented an immense volcanic panorama, the effect of which was greatly augmented by the constant roaring of the vast furnaces below."*

17. Mr. Stewart's visit to Kilauea.—In June, 1825, Mr. Stewart, accompanied by Lord Byron and a party from the *Blonde* frigate, went to Kilauea, and descended to the bottom of the crater.

"The general aspect of the crater," observes Mr. Stewart, "may be compared to that which the Otsego Lake would present, if the ice with which it is covered in winter were suddenly broken up by a heavy storm, and as suddenly frozen again, while large slabs and blocks were still toppling, and dashing, and heaping against each other, with the motion of the waves. At midnight the volcano suddenly began roaring and labouring with redoubled activity, and the confusion of noises was prodigiously great. The sounds were not fixed or confined to one place, but rolled from one end of the crater to the other; sometimes seeming to be immediately under us, when a sensible tremor of the ground on which we lay took place; and then again rushing on to the farthest end with incalculable velocity. Almost at the same instant a dense column of heavy black smoke was seen rising from the crater directly in front, the subterranean struggle ceased, and, immediately after, flames burst from a large cone, near which we had been in the morning, and which then appeared to have been long inactive. Red-hot stones, cinders, and ashes were also propelled to a great height with immense violence; and, shortly after, the molten lava came boiling up, and flowed down the sides of the cone and over the surrounding scoriæ, in most

* Ellis's Polynesian Researches, vol. iv. See also Dana's account of the Hawaiian Volcanos, in his "Geology of the United States Exploring Expedition," 1849; and notices by Messrs. Coan, Weld, and others in the American Journal of Science, and the Journal Geol. Soc. 1856 and 1857; also Lyell's "Manual," p. 491; and De la Beche's "Geol. Observer," 2nd edit. p. 333, &c.

beautiful curved streams, glittering with a brilliancy quite indescribable. At the same time, a whole lake of fire opened in a more distant part. This could not have been less than two miles in circumference, and its aspect was more horribly sublime than anything I ever imagined to exist, even in the ideal visions of unearthly things. Its surface had all the agitation of the ocean; billow after billow tossed its monstrous bosom into the air; and occasionally those from different directions burst with such violence, as in the concussion to dash the fiery spray forty or fifty feet high. It was at once the most splendid and fearful of spectacles."*

The following account, by M. Strzelecki,† of the volcanic phenomena in Hawaii is so highly interesting, that I am induced to insert it entire. "The volcano of Kirauea (Kilauea) lies on the N.W. side of Mauna Roa (Mauna Loa), about twenty miles from the summit of that mountain, and forty from the Bay of Hilo; its latitude is 19° 27'. Its present size surpasses that of every other known volcano, yet it now hardly displays more than one-third of its original magnitude. Its crater must have once been twenty-four miles in circumference, as evidenced by the still remaining ruins of its ancient walls; the highest point of which is 5054 feet above the level of the sea. The sunken furnace of Kirauea is now reduced to eight miles of circumference, the present crater being 4109 feet in height above the sea; which is, therefore, at least 950 feet below the brim of the ancient crater. The edge of this precipice falls perpendicularly 600 feet lower, to the boiling surface of igneous matter. The descent to this level is often precipitous, and winds among a thousand openings, which vomit forth hot vapours, from an area thickly strewed with tabular masses of smoking lava. Like the ice in a blocked-up channel, these tabular masses remain either standing on end, or heaped in horizontal or half-raised beds, and gaping with fissures over fearful cavities, resounding with noises similar to those of a stormy sea. Six of these were in violent agitation while I was exploring the crater. The surface of the fiery matter in all of them kept at about the same height, and rose, sank, and was agitated simultaneously, which seems to show that it belonged to one mass of liquid lava, filling the whole area of the interior of the crater, and that these cavities are mere openings, and the heaps of broken lava which block up part of the crater are a temporary

* Lord Byron's Voyage in the *Blonde* frigate. † New South Wales.

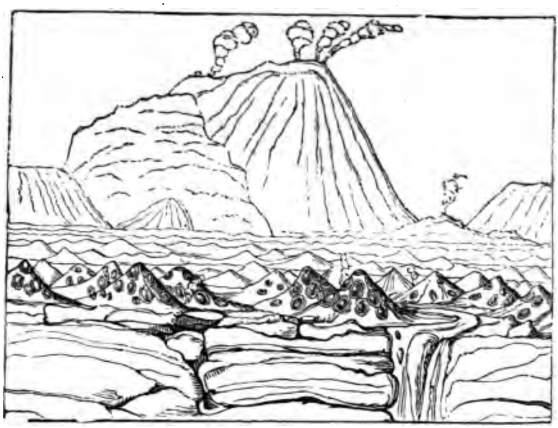
crust or covering over the incandescent mass beneath. The lava of Kirauea appears to be similar to that of Hecla, which is known under the name 'cavernous;' and which, by the intensity of its heat, and the abundance of its elastic gases, produces here, as in Iceland, tumefactions, varying from the thickness and delicacy of a soap-bubble, to the size of caverns twenty or thirty feet wide. These caverns, which extend in every direction, form, beneath the surface of the island, subterranean channels, though which the overflowing lava makes its way, and are often covered by a hollow arch, which yields at once to the tread. Their interior contains the most interesting incrustations of sublimed minerals, with crystalline forms, the perfection of which can hardly be appreciated without the aid of a microscope, and so delicate as scarcely to bear the breath. Mounds of sulphur, more extensive than those of Solfatara, are deposited around the southern plane of the crater.

"On the western flank of the crater above described, the appearances render it probable that the former surface of the incandescent matter was 300 feet higher up than it is at present; and that the opening of the crater of Mauna Roa, which is now 8000 feet above, diverted the course of the intense subterranean heat from that of Kirauea, or at least diminished its intensity. It seems, also, that the incandescent matter of the interior of the crater became refrigerated and solidified in the mighty cauldron; and that after a lapse of time the base on which it stood gave way, under the renewed agency of subterranean heat, when the mass cracked and slipped. A large mass of the solidified lava appears to have fallen again into the abyss, and been remolten: while a part remained lodged against the sides of the cauldron, and is now seen as a rock two hundred feet high, consisting of basalt, trachyte, and lava of several varieties. Between the scoriaceous lava approaching to slag, which lies uppermost, and the close-grained basalt which forms the lowest portion of the rock, the transition is so gradual, that it is impossible to assign the spot where basalt ceases and lava begins. The words, basalt, trachyte, and lava serve, therefore, only to distinguish the upper from the lower part of a stream of molten matter."

18. THE VOLCANO OF JORULLO.—In South America volcanic action has been, and is still, exerted over an immense extent of country; and the vents of the subterranean fires extend to the loftiest summits of the Andes.

In the parallel of the city of Mexico there are no than five burning mountains—Tuxtla, Orizaba, Popoca *Jorullo, and Colima*—arranged as if they [illegible] immense fissure, traversing the region from east to west, and extending from sea to sea.

The elevated country which constitutes the province of Quito is, as it were, an arch or dome, spread over an immense focus of volcanic energy, of which the channels of communication with the atmosphere are the burning mountains of Pichincha, Cotopaxi, and Tunguragua. These, by their grouping, as well as by their lofty elevation and grand outline, present the most sublime and picturesque aspect which is anywhere concentrated within so small a space in volcanic landscape.



LIGN. 201 —VOLCANO OF JORULLO, AND ITS HORNITOS, MEXICO.

(*As seen by Baron Humboldt, about* 1800.)

Eruption of Jorullo.—South America has been the theatre, in modern times, of one of the most extraordinary revolutions in the annals of the physical history of our planet,—that which gave rise to the burning mountain of Jorullo.*

* Baron Humboldt's "Nouvelle Espagne;" see also his "Vues des Cordillères," for beautiful illustrations of Jorullo and its hornitos.

In Mexico there is an extensive plain called the *Malpays*, which was covered by fields of cotton, sugar-cane, and indigo, irrigated by streams, and bounded by basaltic mountains, the nearest active volcano being at the distance of eighty miles. This district is situated at an elevation of about 2600 feet above the level of the sea, and was celebrated for its beauty and extreme fertility. In June, 1759, alarming subterranean sounds were heard, and these were accompanied by frequent earthquakes, which were succeeded by others for several weeks, to the great consternation of the neighbouring inhabitants. In September tranquillity appeared to be reëstablished, when in the night of the 28th the subterranean noise was again heard, and part of the plain of the Malpays,* from three to four miles in extent, rose up like a mass of viscid fluid, in the shape of a bladder or dome, to a height of nearly 1700 feet; flames issued forth, fragments of red-hot stones were thrown to prodigious heights, and through a thick cloud of ashes, illumined by volcanic fire, the softened surface of the earth was seen to swell up like an agitated sea. A huge cone, above 500 feet high, with five smaller conical mounds, suddenly appeared, and thousands of lesser cones (called by the natives *hornitos*, or ovens) issued forth from the upraised plain (*Lign.* 201). These consist of clay intermingled with decomposed basalt, each cone being a *fumarole*, or gaseous vent, from which issued thick vapour. The central cone of Jorullo is still burning, and on one side has thrown up an immense quantity of scorified and basaltic lavas, containing fragments of old crystalline rocks. Two streams, of the temperature of 186° of Fahrenheit, have since burst through the argillaceous

—*Cosmos*, Bohn's Edit. vol. i. p. 227, *note*. Burckhardt states, that during the twenty-four years subsequent to Baron
to Lurullo, the *hornitos* had either wholly d
changed their form.—*Reisen in Mexico*, &c.

* *The tract consisted of porphyritic rocks.*

vault of the hornitos, and now flow into the neighbouring plains. For many years after the first eruption, the plains of Jorullo were uninhabitable from the intense heat that prevailed.

19. SUBMARINE VOLCANOS.—Volcanic eruptions take place indiscriminately either on the land or beneath the waters of the ocean. The igneous foci of Southern Italy are certainly not confined to the land, but extend beneath the bed of the Mediterranean; and of this the occasional appearance of new shoals and islands affords conclusive evidence. Livy informs us that an event of this kind, which took place about the period of the death of Hannibal, together with other volcanic phenomena, so terrified the Roman people, as to induce them to decree a supplication to the gods, to avert the displeasure of heaven, which these prodigies were supposed to denote. "Nuntiatumque erat haud procul Sicilià insulam quæ nunquam ante fuerat novam editam e mari esse."—LIVY, lib. xxxix. c. 56.

In Iceland, which may be regarded as a partially submarine volcanic mountain, with the highest summits above the waters, eruptions are not restricted to the area of dry land; but often burst out in submarine volcanos off the coasts. The enormous eruptions which issued from three different vents in the low tract called Shaptar Jokul, in 1783, and poured out lava-currents many miles wide, and ninety long, was preceded by the appearance of volcanic cones, vomiting flames and vapour, in the neighbouring sea, many miles from the land.*

A highly interesting example of the emergence of a submarine volcano took place in 1831. A volcanic island suddenly arose in the Mediterranean, about thirty miles off the S.W. coast of Sicily, where previous soundings had ascertained the depth of the sea to be 600 feet. It was preceded

* "Travels in the Island of Iceland, during the Summer of the year 1810." By Sir George Stewart Mackenzie, Baronet, 4to, 1811.

by a violent spouting up of steam and water, and at length a small island gradually appeared, having a crater on its summit, which ejected scoriæ, ashes, and volumes of vapour; the sea around was covered with floating cinders and shoals of dead fishes. The crater attained an elevation of nearly 200 feet, with a circumference of about three miles, having a circular basin full of boiling water of a dingy red colour. It continued in activity for three weeks, and then gradually disappeared. The island received various names; but it is best known by the English name of "Graham's Island," and the French one of "l'Isle Julia." In 1833, two years after

LIGN. 202.—VOLCANIC ISLAND THROWN UP IN THE MEDITERRANEAN IN 1831.

its destruction, a dangerous reef remained, eleven feet under the water; in the centre of which was a black volcanic rock (probably the remains of the solid lava ejected during the eruption), surrounded by shoals of scoriæ and sand. The appearance of the island, when visited by M. Constant Prévost,* is shown in this sketch (*Lign.* 202), from a draw-

* See his "Rapport sur le Voyage à l'Ile Julia en 1831 et 1832." Also Annales des Sc. Nat. 1831, vol. xxiv. p. 103.

ing with which he favoured me. From these facts it is certain that a hill, 800 feet high, was here formed by a submarine volcanic vent in the course of a few weeks. The occurrence of shoals of dead fish will not fail to remind you of the ichthyolites of Monte Bolca (p. 269): and there can be no doubt that vast numbers were ingulfed in the erupted mineral masses at the bottom of the sea; and when this ocean-bed shall be elevated above the waters, and explored by some Agassiz of future times, the then fossil fish of the Mediterranean, imbedded in volcanic tuff, will afford interesting subjects for the contemplation of the geologist and the philosopher.

20. SUMMARY OF VOLCANIC PHENOMENA.—I have indulged in the foregoing long extracts, because the vivid pictures which they present of volcanic action cannot fail to produce a powerful impression on the mind, and cause it to revert to the principles enunciated in the first Lecture, which suggest the probability that the earliest condition of the earth, and of the worlds around us, may have been that of vapour or fluidity (p. 48). Here we see the most solid and durable materials of the globe reduced to a liquid state—seas of molten rocks, with their waves and billows, their surge and spray, giving birth to torrents and rivers, which, when cooled, become the hardest and most indestructible mineral masses on the surface of our planet!

The constant escape of aeriform fluids from volcanic vents,—the irresistible force which such elastic vapours exert when pent up and compressed—an effect with which our steam-boats and locomotive engines have made every one familiar,—and the immense production of such gaseous elements which must be taking place in the interior of the globe from the igneous action which is going on unremittingly, afford a satisfactory explanation of the nature and cause of earthquakes,* and of those elevatory movements by

* See "Geol. Observer," 2nd edit. p. 415, &c.; Daubeny's "Vol-

ch the foundations of the deep are broken up, and raised
› chains of mountains, thousands of feet above the level
the sea. The volcanic vents are, in fact, the safety-
res by which the caloric and the gaseous fluids from the
rior of the earth escape into the atmosphere; when these
nnels become choked up, the confined gases occasion
thquakes, dislocations of the rocks and strata, and eleva-
ns of the land, and at length escape either through the
ner vents or by opening new channels. Hence, in the
guage of Humboldt, the volcanic force must be contem-
ted as *formative* of new rocks, and *transformative* of
se which were preëxisting. But the volcanic operations
v going on are only a faintly reflected image of that energy
ich took place in the earliest geological epochs, under
y different terrestrial and atmospheric conditions. The
t chasms and fissures which it is probable existed in the
d portions of the earth's crust in the ancient periods,
m the contractions which must have taken place before
rigeration had proceeded so far as to admit of accumula-
ns of aqueous sediments on the primary mineral masses,
e since been closed by the protrusion of mountain-chains
ough them, or filled up by dykes of granite, porphyry,
l basalt.*

As the fragments of unmelted rock, which are occasionally
own up from the foci of volcanos apparently of enormous
pth, consist of granite, quartzose porphyry, and the like,
ne philosophers are of opinion that a primitive granitic
k was the substratum, and is the support, of the super-
posed sedimentary and fossiliferous strata.

Intense heat and chemical changes, which evolve gaseous
pours and fluids, are necessarily the immediate elements

os," 2nd edit. p. 507, &c.; and especially Phillips's "Manual of
logy, 1855," p. 560, for a résumé of the latest researches and opinions
earthquakes and their causes.

* Cosmos, vol. i. p. 197, &c.

in volcanic action; and the volume of gas and vapour is often so great as to uplift the molten lava, and at length to burst through and escape in violent explosions. Without being able to determine the precise nature of the first link in the chain of volcanic action, we may reasonably infer that the play of electro-chemical and electro-magnetic forces, which must be incessantly going on among the heterogeneous mineral substances of which the earth consists, is a main agent in producing the varied effects we have been contemplating.*

Many ingenious theories have been proposed to account for the immediate cause of volcanic action. Of these, the oxidation of the metallic bases of certain earths and alkalies by percolations of water into deep-seated beds of these substances, suggested by Sir Humphrey Davy, is still powerfully advocated by a high authority—Dr. Daubeny; but proof that such bases do exist in a metallic state in the interior of the earth is required, before the hypothesis, however ingenious, can be admitted as a *vera causa*.†

From the late researches of Wöhler, Deville, and Daubeny, it appears that boron and titanium, and probably other metals, such as iron, and possibly even hydrogen, under certain conditions, unite with gaseous nitrogen with such energy as to generate light and heat; thus constituting a genuine case of combustion in which nitrogen, and not oxygen, acts as the supporter. The combination of these substances would thus furnish, like the oxidation of potassium and other metalloids, a direct cause of volcanic fire; and the subsequent decomposition of their nitrides might be the

* The various theories that have been proposed to explain volcanic action are considered with great candour and perspicuity by Sir H. de la Beche, in his "Researches in Theoretical Geology." See also Daubeny, *op. cit.* chapters 38 and 39.

† The phenomena attendant on the combination of oxygen with potassium, sodium, &c.—the rapid and violent evolution of heat, light, and expansive force—must be familiar to the intelligent reader

origin of the ammonia often evolved from volcanos in vast quantities.*

Another hypothetical cause of volcanic action has been brought forward by Mr. S. Macadam,† based on the known conditions of bodies in a "spheroidal" state. Arguing from the properties of water in a spheroidal state, Mr. Macadam suggests that water, having access to subterranean cavities connected with the central nucleus of fused mineral matter, assumes the spheroidal condition, until, a large quantity of water having collected together, it takes sufficient heat from the metallic surface to destroy the equilibrium of repulsion, and, touching the metallic basin, it is in great part suddenly converted into steam,—the mineral substances are chemically affected,—and large quantities of explosive vapour and gases soon acquire sufficient force to raise great tracts of land, and to burst through the surface, bringing up the fused materials of volcanos.

It is worthy of remark that there are active volcanos both in the Arctic and Antarctic regions. Sir James Ross observes that "the earth's crust, as we approach towards the pole in the southern hemisphere, presents the most striking indications of the vast subterranean fires pent up within it, —and, as we now find, having vent in both the frigid zones: the volcano of Jan Mayen actively burning within the Arctic Circle; and Mount Erebus, rising from the lofty mountain range of the newly-discovered continent of Victoria, to an altitude of more than 12,000 feet above the Antarctic Ocean, and sending forth its smoke and flame to the height of 2000 feet above its crater, the centre of volcanic action in those regions of eternal snow."‡

* Geol. Proceed. January 20, 1858.

† In a paper "On the Central Heat and Density of the Globe, as also the Causes of Volcanic Phenomena," Report Brit. Assoc. 1850, rep. sect. p. 88.

‡ Sir J. C. Ross's "Voyage to the Southern Seas," vol. ii. p. 412.

21. HYPOGENE ROCKS.*—We must now enter upon a more particular examination of the *Hypogene* (nether-formed) or metamorphic and plutonic rocks;† those crystalline rock-masses which everywhere manifest the influence of intense heat under great pressure. It will be convenient to consider them under two heads: viz. 1st, the rocks which present a stratified or laminated structure, as mica-schist, gneiss, &c.; 2ndly, those which occur in amorphous masses, as granite, porphyry, &c.; including, in this group, the ancient volcanic products, trap-rocks, basalt, &c., a notice of which we found it requisite to anticipate, when investigating the fossiliferous strata traversed by dykes of these substances.

And here it is necessary to premise, that an acquaintance with the nature and appearance of the minerals that are the usual components of crystalline rocks is indispensable to enable the reader to have a clear conception of the facts that will come under his notice. This knowledge can only be acquired by the study of specimens; and it would be useless to attempt by mere description to teach the elements of mineralogy. In these Lectures I must assume either that such knowledge is possessed by my readers, or that they will rest satisfied with a general idea of the leading phenomena embraced in this division of the subject.‡

* See vol. i. p. 206.

† For guide-books in the study of the characters and classification of rocks, the reader is referred to those by Macculloch, Brongniart, Cordier, Cotta, Erdmann, Naumann, Senft, Dana; &c.

‡ The elementary mineralogical knowledge necessary for this purpose may be acquired by the study of a suite of specimens to be obtained of Mr. Tennant, 149, Strand, Professor of Mineralogy in King's College. If the student can have the advantage of a few private lessons from Mr. Tennant, or can attend the lectures delivered in King's College, or those by other Professors at the London University College, the School of Mines, and other Institutions, his progress will be more rapid and satisfactory than by any other method. For the advanced student, the "*System* of Mineralogy," by James D. Dana (new edition), New

Mica-schist and Gneiss.—The stratified, laminated, or foliated metamorphic * rocks consist of two chief groups. The first, and usually uppermost, is *Mica-schist*, a schistose rock, abounding in a mineral called *mica* (from its glittering appearance), and in *quartz*, a substance of which rock-crystals and the semi-transparent pebbles common in most beds of shingle or beach are examples. These two minerals are disposed in alternate layers, forming laminæ of greater or less thickness, which are extremely contorted and undulated. Some of these masses, especially in the upper portion, bear a considerable resemblance to the metamorphic argillaceous schists; the lower are of a more quartzose character, probably from having been subjected to a greater degree of igneous action.

Gneiss † consists of laminated and contorted bed-like masses of quartz, felspar, and mica, irregularly alternating; and may, in truth, be regarded as laminated granite, for the same substances enter into their composition as prevail in the amorphous masses of that rock. Gneiss is often found associated and alternating with mica-schist, quartz-rock, clay-slate, and hard granular limestone. The whole series of stratified metamorphic beds may therefore be considered as partaking of one common mineralogical character, and, with the exception of the calcareous rocks, may have originated from the disintegration and subsequent consolidation of more ancient crystalline masses.

The stratified appearance of gneiss and mica-schist is attributed by some geologists to an arrangement of crystals of different specific gravities in horizontal planes; their subsequent softening by heat admitting of the flexuosities

York; Brooke and Miller's edition of Phillips' Mineralogy; Nicol's Mineralogy; and Mitchell and Tennant's Mineralogy (Orr's Circle), will be found among the best works on the subject in the English language.

* The metamorphic rocks are termed "hypozoic" (or below life) rocks by Phillips: see his "Manual," chap. 5.

† A German mining term.

of these rocks. Others * believe that melted granite, upon cooling under particular circumstances, would assume a stratified or ribboned appearance, analogous to that of gneiss; or might even resemble in structure some aqueous sediments.

From the researches of Mr. H. C. Sorby it is evident that, whilst some mica-schists are truly sedimentary laminated beds, formed of the debris of older granitic rocks, others are altered rocks, which owe their foliated character, as in the case of cleavable slate-rocks (p. 835), to violent pressure (and perhaps chemical changes) at periods subsequent to their original formation.†

There are various substances associated with this group, as hornblende-schist, a black or grey rock, chlorite-schist, a green slaty rock, and the beautiful mottled magnesian rock called *Serpentine*, with steatite; the latter are often connected with trap.

Granite (so named from its granular structure) is the foundation upon which all the strata of which we have spoken are superimposed, and the framework of the earth's crust; rising to the loftiest heights, and stretching into mountain-chains, which mark the grand natural divisions of the physical geography of the globe.

Although presenting great variety in the proportion and colour of its ingredients, granite is essentially composed of three substances, which may be easily recognised in the blocks of which many of our pavements, bridges, roads,

* Especially Naumann and Scrope; "Considerations on Volcanos;" Neues Jahrb. 1847, p. 297; Quart. Journ. Geol. Soc. vol. iv. part 2, Miscell. p. 1; *ibid.* vol. xii. p. 345; and above, p. 856.

† Report Brit. Assoc. 1856, rep. sect. p. 78. In a paper by Mr. D. Forbes, "On the Relations of the Silurian and Metamorphic Rocks of the South of Norway," in the Edinburgh New. Phil. Journ. new series, January, 1856, we have an ingenious attempt to show that the foliated rocks of much of that district can be hypothetically related to certain more or less horizontal lines, at right angles to the existing vertical planes of the schists, and representing the lines of bedding previous to the metamorphic [illegible] which have induced their present vertical foliation.

and other works are constructed. These are *mica*, known by its silvery or glittering aspect,—*quartz*, by its glassy appearance,—and *felspar*,* which forms the opaque white, pink, or yellowish masses, oftentimes seen in sections as long angular crystals, which from their size and colour may be readily detected, even by the unscientific observer. In some species of granite, *talc* and *hornblende* occur, and the mica is wanting; in the former case the rock is called *protogine;* in the latter *syenite:* those masses which are composed of crystals of felspar in a base of compact felspar constitute *porphyry*.

M. Bischof states that it may be demonstrated mathematically that all the sedimentary strata, and all the substances enclosed in drusy cavities, are derived from the plutonic crystalline rocks; these have furnished the materials, and water has conveyed the quartz, calcareous spars, heavy spars, metals, and other substances which fill such cavities.

One of the most important advances towards a knowledge of the exact nature and origin of granite has been made by Mr. H. C. Sorby, in his memoir, "On some Peculiarities in the Microscopical Structure of Crystals, applicable to the determination of the Aqueous or Igneous Origin of Minerals and Rocks," read before the Geological Society in December, 1857. In this paper many curious facts were described, relating to the minute cavities contained in nearly all crystals, and sometimes occupied by fluid, sometimes by stony matter; and it was shown that many crystals must have formed when both melted rock and water were present; this water being in such an expanded state as would indicate a red heat, since some of the "fluid-cavities" in the crystals serve as self-registering thermometers. It turns out that granite is a rock that was formed in this way. It is an

* Kaolin or porcelain-earth is formed by the decomposition of alkaline felspar. "See Mémoire sur les Kaolins ou argiles à porcelaine," by M. *Alex. Brongniart; Archives du* Muséum d'His. Nat. 1839 and 1841.

aqueo-igneous rock; being really due to combined agency of both water and fire: and hence, observes Mr. Sorby, have arisen the discussions as to which it is—Neptunian or Plutonic. Indeed Mr. Sorby finds in some minerals ejected from volcanos, and probably formed deep down at their base, conditions analogous to those which he observes in granite.*

22. MICA-SCHIST AND GNEISS.—These rocks are widely spread over and around the masses of unstratified plutonic rocks. They occur in Caernarvon and Cumberland, but are of inconsiderable extent in England. In Scotland they extend over great part of the Highlands, and largely prevail in the Hebrides; they form mountain-ranges in the north of Ireland, and cover large areas in Londonderry and Donegal.

The gneiss of the Northern Highlands is of two distinct ages. There is the old gneiss of Cape Wrath and the shores of Rosshire, on which rests the Cambrian conglomerates of the Ross Mountains (see p. 806); and the younger gneissose rocks of the eastern part of Sutherland, which overlie the fossiliferous limestones of Durness, and are altered strata of Silurian age. An instance of secondary gneiss resting on lias occurs in Switzerland.

The most striking features of these rocks are the flexures and contortions in which they are so generally folded; proving the soft and ductile state in which the component materials must have existed; for they present every variety of sinuosity and curvature imaginable.

The Isle of Lewis (one of the Hebrides), so admirably illustrated by Dr. Macculloch, is remarkable for the contortions observable in its precipitous cliffs of gneiss, and the innumerable granite-veins with which they are traversed. The face of the rocky cliffs appears like veined marbled paper; and the imagination can scarcely conceive an intri-

* See Appendix A.

cacy or interlamination of this nature, of which a resemblance could not be found in the cliffs of Lewis.*

From the decomposition and falling away of the sur-

LIGN. 203.—CURVED GNEISS IN THE ISLE OF LEWIS.
(From Dr. Macculloch's Western Isles.)

rounding parts of the rocks near Oreby, an interesting, perhaps solitary, example occurs of a bent and detached mass of gneiss, about thirty or forty feet high (*Lign.* 203), and which forms a highly interesting and picturesque object.

23. Contortions of crystalline rocks.—The curvatures and flexures of rocks largely composed of quartz is a subject of great interest in another point of view, because it bears upon the question as to the solution and deposition of silex; a process which appears to have been going on in the crust of the earth from the formation of the most ancient granitic rocks to the deposits now in progress. I have before remarked, that the appearance of some of the

* Western Isles, p. 193.

silicious infiltrations in the tissues of sponges, ventriculites, and other zoophytes, and even in the intimate structure of wood,* when seen under a highly magnifying power, is that of a viscid fluid, or plastic paste, pressed into the interstices of the tissue, rather than that of the percolation of a mineral solution, or of a metamorphism of the organism, as in other examples of silicified animal and vegetable structures.

Experiments have shown that melted quartz, unlike alumina, retains its viscidity for some time when cooling, and may be drawn out in threads;† and M. Jobert states, that in graphic granite he has found the quartz-crystals in the midst of the felspar flattened and contorted, as if they had been strongly pressed between the felspathic matter.‡

These facts seem to offer an explanation of the flexures and curvatures in quartz-rocks and gneiss: and they are brought forward by Mr. Darwin, with his usual acumen, to illustrate the origin of the remarkable duplications, and abruptly arched positions, of the stratified quartz-rocks in the Falkland Islands. Some of the hills, he observes, are composed of quartz-strata doubled on themselves, with the axis-plane thrown quite over,—the quartz must therefore have

* As for example, in some of the fossil wood from Egypt and Australia; see p. 727.

† M. Gaudin, quoted by Mr. Darwin.

‡ M. Alexander Brongniart attributes the formation of all agates and chalcedonies to the viscous or gelatinous condition of the mineral matter; and that of hyaline quartz and rock-crystal to the perfect fluidity of the dissolved silica. "Lorsque la silice a été complètement dissoute, et par conséquent dans un état de liquidité parfait, elle a cristallisé et produit le quarz hyalin. Mais lorsqu'elle était en consistance gélatineuse, elle a produit les silex et surtout ceux qu'on désigne par le nom général d'agate et de calcédoine."—*Essai sur les Orbicules siliceux.* Ann. Sciences Nat. 1831, vol. xxxiii. p. 200.

In the specimen of Trigonia from Tisbury, previously mentioned (*p. 527*), the *branchiæ* are completely silicified; and some of these filaments, when examined under a high power, show the orbicular structure which characterizes chalcedonic silica.

been in a pasty condition when it suffered without fracture such abrupt curvatures. Mr. Darwin states that the detached concentric layers resembled gigantic semi-cylinders of quartz, like draining- or ridge-tiles. One specimen was twenty feet long and twelve in diameter.*

It would appear, therefore, that silex or quartz may be formed in two ways: by the action of thermal waters (p. 93, &c.), and by the influence of intense heat. The remark of Professor Keilhau here applies with equal force as to the experiments which called it forth:—"The greater part of the crystalline rocks have an entirely hidden origin and development. Chemistry alone cannot decide this question, for the same minerals can be composed in nature by different processes. By the side of the celebrated fact which showed the possibility of the formation of felspar by heat, we can now place experiments which prove the possibility of producing felspar in the moist way."

Mica-schists and gneissic rocks are widely expanded over Europe and America; and everywhere abound in metalliferous veins. They are of various ages; and their metamorphic character is proved by the occurrence of gneiss, mica-schist, and talcose-schist in the Alps, Apennines, Andes, and Alleghanies under circumstances showing that their crystalline structure has been acquired since the origin of many of the fossiliferous strata; even in some instances long after the deposition of those which repose directly upon them. On the other hand, the gneiss of Kinnekulle in Sweden, or of the Falls of Montmorenci, and many of the unstratified or plutonic rocks of the Adirondach mountains, west of Lake Champlain, are of older date than any strata in which organic remains have yet been found.†

In the North Highlands of Scotland, as already stated

* Mr. Darwin, On the Geology of the Falkland Islands; Quarterly Geological Journal, vol. ii. p. 267.

† *Sir C. Lyell's Travels* in America, vol. ii. p. 129.

(p. 809), we have both an old primordial gneiss and a younger metamorphic gneiss within a section of a few miles in length.*

24. Basalt or Trap.—The consideration of the ancient volcanic rock designated by the various names of *Whin*, *Trap*, *Basalt*, and *Clinkstone* will next engage our attention. Basalt occurs in veins or dykes, which traverse rocks of all ages; it also occurs in layers spread over the surface of the strata, or interposed between them. Many modern lavas differ so little from basalt, that it is unnecessary to adduce proof of the volcanic nature of this rock. Dr. Macculloch observes, that from lava to basalt, and from thence to syenite, porphyry, and granite, there is an uninterrupted succession: *as agents in geological changes trap and granite are identical;* and that it is a mere dispute about terms to refuse the name of submarine lavas to basaltic dykes. They are as much the product of extinguished volcanos, as the basalts, lavas, and tuffs of Italy are the result, in some cases, of extinct, and, in others, of active volcanos.† Beds of felspathic and basaltic materials, of a friable and coarse texture, are often found in the older rocks; these are volcanic ashes and grits, that have been formed at the bottom of the sea, during the accumulation of the sedimentary matter with which they are associated (p. 818). In some places they appear as currents or sheets of pure volcanic materials; at others they envelope marine remains, pebbles, sand, and fragments of rocks; some layers consist of fine volcanic scoriæ passing into sand; and all these varieties alternate with beds composed exclusively of shelly and marine sediments; so that no doubt can be entertained that the diversified masses, thus arranged in parallel strata, must have been formed during the same period of igneous action. These evidences of ancient volcanic operations are similar to those observable in the modern deposits of Sicily, where banks of existing species

* See "Siluria," 2nd edit. p. 199. † System of Geology, vol. ii. p. 114.

of marine shells, now at considerable heights above the sea, are so intercalated with volcanic matter, that no other inference can be drawn than that the whole were of contemporaneous marine formation.*

The most remarkable form assumed by basalt is that of regular pillars, or columns, clustered together; a character also observable in some recent lavas; the columnar basalts of the tertiary epoch have already been noticed (vol.i. p.271). This columnar structure has been proved, by some highly interesting experiments, to have originated in the manner in which refrigeration took place. Mr. Gregory Watt† melted seven hundred weight of basalt from Rowley Regis (p. 813), and kept it in the furnace several days after the fire was

LIGN. 204.—BASALTIC COLUMNS, FROM THE GIANTS' CAUSEWAY.

Fig. 1. A block somewhat decomposed, partially exhibiting the primitive spheroidal figure of the prism. 2. Portions of columns, consisting of several joints. 3. The concave surface of a joint.

reduced. It fused into a dark-coloured vitreous mass with less heat than was necessary to melt pig-iron; as the mass cooled, it changed into a stony substance, and globules appeared; these enlarged until they pressed laterally against each other, and became converted into *polygonal prisms.*‡

* Silurian System, p. 75. † Philosophical Transactions for 1804.
‡ "Geol. Observer," p. 404.

The articulated structure and regular forms of basaltic columns have, unquestionably, resulted from the crystalline arrangement of the particles in cooling; and the concavities, or sockets, have been formed by one set of prisms pressing upon others, and occasioning the upper spheres to sink into those beneath; thus the different layers of spheres have been articulated together, as in the basaltic columns of the Giants' Causeway (*Lign.* 204).

Proofs of the correctness of this inference are afforded by the occurrence of a spheroidal nucleus enveloped by a polyhedral block of basalt; and from the fact, that, when this rock is not divided into regular prismatic columns, it often forms laminated spheroids, which, varying in size, constitute by aggregation extensive masses. The position of the columns presents every variety from the perpendicular to

Lign. 205.—The Isle of Staffa.

the horizontal; this has arisen from corresponding differences in the direction of the cooling surfaces, for the prisms are found to be always at right angles with the surface of refrigeration; the horizontal, inclined, and curved columns of basalt, which occur in the Isle of Staffa, and elsewhere, have originated from this cause.

25. ISLE OF STAFFA; FINGAL'S CAVE.—Many of the Hebrides, or Western Isles of Scotland, are almost wholly composed of trap-rocks. Of these Staffa* is the most celebrated, on account of a deep chasm or recess situated in a magnificent group of vertical columnar basalt, and which has been produced by the incessant action of the surges on the base of the cliff. This natural cavern is of singular beauty, and is known to the English tourist by the name of *Fingal's Cave;* but it is called by the islanders *Naimh-bim,* or the Cave of Music, from the murmuring echoes occasioned by the billows, which in rough weather dash with violence and a loud noise into the chasm.

The Isle of Staffa is a complete mass of columnar basalt; it is about two miles in circumference, and forms a table-land of an irregular surface, being surrounded on every side by steep cliffs, about seventy feet high, which are composed of clusters of angular columns, possessing from three to six or seven sides. It is intersected by one deep gorge, which divides the higher and more celebrated columnar portion from the other division of the island. At the highest tides, the columns which form the south-western cliffs appear to terminate abruptly in the water; but the retiring tide exposes a causeway of broken columns at their base. The greatest elevation of the island is about 120 feet, and its surface is covered with soil of considerable depth, clothed with herbage.†

Fingal's Cave, first made known to the public in 1772, by Sir Joseph Banks, is on the south-east corner of the island, and presents a magnificent chasm 42 feet wide, and 227 in length. The roof, which is 100 feet high at the entrance, gradually diminishes to 50, and is composed of the projecting extremities of basaltic columns; the sides are formed of perpendicular pillars; and the base consists of a causeway paved with the truncated ends of similar columns.

* *Staffa,* a Norse term, signifying a staff or column. † Dr. Macculloch.

The vaulted arch presents a singularly rich and varied effect; in some places it is composed of the ends of portions of basaltic pillars, resembling a tessellated marble pavement; in others, of the rough surface of the naked rock; while in many, stalactites mingle with the pillars in the recesses, and add, by the contrast of their colours, to the pictorial effect, which is still further heightened by the ever-varying reflected light thrown from the surface of the water that fills the bottom of the cave.

The depth of the water is nine feet, and a boat can therefore reach the extremity of the cave in tolerably calm

LIGN. 206.—FINGAL'S CAVE; VIEWED FROM WITHIN.

weather; but, when the boisterous gales of that northern clime drive into the cavern, the agitated waves, dashing and breaking against the rocky sides, and their roar echoed with increased power from the roof, present to the eye and ear such a scene of grandeur as bids defiance to any description. The short columns composing the natural causeway before mentioned continue within the cave on each side, and form a broken and irregular path, which allows a skilful and fearless climber to reach the extremity on the eastern side on foot: but it is a task of danger at all times, and impossible at high tide, or in rough weather. It would be useless, observes Dr. Macculloch, to attempt a description of the picturesque effect of a scene which the pencil itself is inadequate to portray. Even if this cave were destitute of that order and symmetry, and that richness arising from the multiplicity of its parts, combined with its vast dimensions and simple style, which it possesses, still the prolonged length, the twilight gloom half concealing the playful and varying effects of reflected light, the echo of the measured surge as it rises and falls, the transparent green of the water, and the profound and fairy solitude of the whole scene, could not fail strongly to impress a mind gifted with any sense of beauty in art or in nature.*

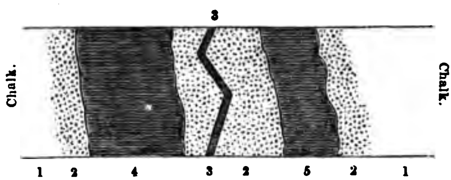
The basalt of which the columns are composed is of a dark greenish-black hue; a thin layer of silicious cement occurs between the joints or articulations, which is called mortar by the islanders, and strengthens their persuasion that this wonderful cave is the work of art. Another cave, but of inferior dimensions, lies at a short distance; and many others of less note are seen in various parts of the cliffs, into which the sea breaks with a noise resembling that of distant heavy ordnance.

26. Strata altered by contact with Basalt.—In Ireland a magnificent range of basaltic pillars extends along the northern coast of Antrim. It consists of an irregular group of hundreds of thousands of pentagonal, jointed, basaltic columns, varying from one to five feet in thickness, and from twenty to two hundred feet in height. The structure of these masses I have already described; their prevailing colour is a dark greenish-grey. Along the shore, a vast area is covered by the truncated ends of upright

* Macculloch's Western Isles.

columns, the upper parts of which have been swept away by the action of the waves. The surface, therefore, presents the appearance of a pavement composed of enormous angular blocks of stone; whence has originated the popular name of the *Giants' Causeway*. In the cliffs, a natural cavern has been excavated by the inroads of the waves, about sixty feet high, and of great picturesque effect; the entrance is nearly thirty feet in width, and the walls are formed of dark basalt.

But the great interest of this spot, in a geological point of view, is the altered structure observable in the sedimentary rocks wherever they are in contact with the basalt. The Chalk, in this part of Ireland, constitutes a line of cliffs traversed by trap, which occurs in vertical dykes, and in extensive beds, and has a columnar structure.



LIGN. 207.—TRAP-DYKES TRAVERSING CHALK: IN THE ISLE OF RATHLIN.*

1, 1. Chalk.
2, 2, 2. Chalk changed into granular marble by contact with the Trap-dykes.
3. A narrow Trap-dyke or vein (1 foot thick) traversing altered Chalk.
4. Trap-dyke, 85 feet wide.
5. Trap-dyke, 20 feet wide.

The chalk-strata have a total thickness of about 270 feet, and rest on a green sandstone, called *mullattoe*, which is the equivalent of the Upper Greensand of the south-east of

* See the Memoir by Conybeare and Buckland, Geol. Trans. vol. iii. p. 196, &c. The student may also with advantage consult Portlock's "Report on Londonderry," &c. for an account of the Chalk and Basalts of the Antrim coast; also Mr. E. Hall's paper in the Edinb. New. Phil. Journ. new series, vol. v. p. 53.

ngland (vol. i. p. 301); it contains flint-nodules, ammo-tes, belemites, echinites, terebratulæ, and other usual ssils of the cretaceous formation.

In the Isle of Rathlin, nearly vertical dykes of basalt are en intersecting the chalk (as in this sketch, *Lign.* 207), hich at the line of contact, and to an extent of several feet om the wall of the dyke, is completely metamorphosed. iose portions of the chalk which have been exposed to the treme influence of the trap are now a dark-brown crys-lline rock, the crystals running in flakes, like those of arse crystalline limestone; in the next state the rock is of saccharoid structure; then fine-grained and arenaceous; a mpact variety with a porcellaneous aspect, and of a bluish-ey colour, succeeds; this gradually becomes of a yellow-h-white, and passes insensibly into unaltered chalk.* The ints in the hardened chalk are either of a yellowish or deep-d colour, and the chalk itself is highly phosphorescent. The ssils are much indurated, but retain their usual appearance.

To the south of Fairhead, in the county of Antrim, yenite traverses mica-schist and chalk, and fragments of ie latter are impacted in the erupted mass, being changed ito granular marble.† The geological structure of that art of Ireland consists of—1. The underlying rock, Mica-chist; 2. Coal-shale; 3. Triassic strata; 4. Chalk.‡

In this place it is necessary to remind the reader of the camples of intruded basaltic rocks which have been no-ced in the former part of this lecture, when treating of the alæozoic formations; viz. the trap of Dudley (p. 700 and 11), of the Malvern and Abberley Hills (p. 815 and 18), &c.; the toad-stones of Derbyshire (p. 698), and the

* Dr. Berger on the Geological Features of the North-east of Ireland, ol. Trans. 1st ser. vol. iii. p. 172.

† The beautiful statuary marble of Carrara is jurassic limestone, tamorphosed by the influence of contiguous igneous rocks.

‡ Mr. Griffiths, Trans. Geol. Soc. 2nd ser. vol. v. p. 179, &c.

Whin-sill* of Yorkshire. The latter is an enormous basaltic dyke, which traverses the island from the Tees to Robin Hood's Bay, and intersects all the strata from the lowermost beds of the coal-measures to the oolite inclusive.

27. Trap-dykes in the Isle of Skye.—In the Isle of Skye the intrusions of basalt are on a large scale, and present many important and instructive examples of the disturbance and altered character of the sedimentary rocks, that have been exposed to their influence. From the numerous sketches that illustrate Dr. Macculloch's work on the Western Isles,† I have selected the one before us (*Lign.* 208), as exhibiting vertical, oblique, and horizontal

Lign. 208.—Trap-dyke on the coast of Trotternish, in the Isle of Skye.

a, Vertical Trap.
b, c, d, Trap-veins sent off from the mass *a*.
e, Strata of sandstone.

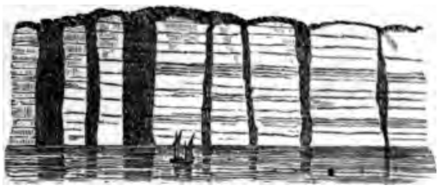
veins or dykes; a large mass of trap is seen abutting, at *a*, against the sandstone-strata *e*; and giving off a thick horizontal stream, which sends off branches both upwards (*b*) and downwards (*d*), and finally divides into three small veins (*c, c, c*).

In the cliffs at Straithaird, in the Isle of Skye, the sandstone-strata are traversed by numerous vertical dykes and veins of trap; and the latter in many places have decom-

* See Prof. Sedgwick's valuable Memoirs, on the Trap-rocks of Yorkshire and Durham, in the Transact. Cambridge Phil. Soc. vol. ii. p. 21, and p. 139.

† This work should be referred to, in order to obtain an adequate idea of the extent and complexity of the trap-dykes and veins in the of Skye and others of the Hebrides. See also Mr. Geikie's Memoir the Geology of Strath in Skye, Quart. Journ. Geol. Soc. vol. xiv. p. 15

posed, and left perpendicular fissures, as is shown in the annexed sketch (*Lign.* 209); the reverse of the phenomena observable in the Val del Bove (p. 865).



LIGN. 209.—VERTICAL CHANNELS IN SANDSTONE-STRATA, LEFT BY DECOMPOSED TRAP-DYKES; AT STRAITHAIRD, ISLE OF SKYE.
(*Dr. Macculloch's Western Isles.*)

Porphyritic dykes and veins also occur abundantly in the same island, in some instances protruding through, and in others spreading over clay-slate, red sandstone, and shelly limestone.

In some of the slate-districts, where the trap has burst through and overflowed the strata, fragments of slate are found imbedded in the basalt, appearing to have been detached from the rock at the intrusion of the lava, and enveloped while the latter was in a state of fusion.

Sometimes the fractures and displacements of the strata are on so small a scale as to exhibit the relative connexion of the separated portions, as shown in this sketch of trap intruded between sandstone, in the Isle of Arran (*Lign.* 210, *fig.* 4). This island, which is the largest in the Firth of Clyde, presents, like the Isle of Wight in the south-east of England, an epitome of the geology of the neighbouring mainland. There "the four great classes of rocks—the fossiliferous, volcanic, plutonic, and metamorphic—are all conspicuously displayed within a very small area, and with their peculiar characters strongly contrasted." *

* Lyell's Manual, 5th edit. p. 589. I much regret that my limits will not admit of a detailed notice of this most interesting island; we

28. GRANITE.—Various modifications of the compound mineral termed granite (see above, p. 882) constitute a great proportion of the hypogene rocks, and are found almost everywhere beneath the gneiss and mica-schist, and often in contact with strata of the secondary and even tertiary formations. In the British Isles granite appears in Galway, Donegal, Armagh, and Down, Wicklow and Carlow;* in Cornwall and Devon; Pembrokeshire; Anglesea; Kirkcudbrightshire; Aberdeenshire, &c.; and forms the nucleus of Skiddaw, Shapfell, Ben Nevis, and other mountain-peaks.

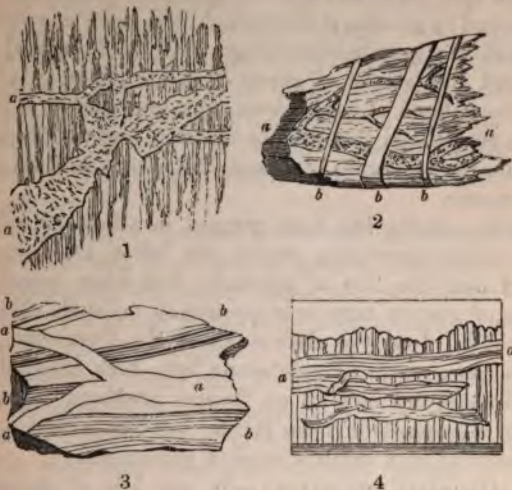
Granite-veins.†—Granite often occurs in dykes and veins which traverse not only other rocks, but also the preëxisting masses of granite; proving that the formation of this mineral has taken place at various and distant periods. Veins are fissures or chasms produced in rocks either by mechanical disturbance, or by contraction of the mass during its consolidation or refrigeration, and which have been filled by subsequent infiltration or sublimation, or by injections of mineral matter in a state of fusion from a subterranean source. Although many metallic veins are synchronous with the rocks they traverse, having been formed by segregation during the consolidation of the mass, yet the veins and dykes of volcanic matter are obviously of later

must refer the reader to the work cited, and to the excellent guide to the Geology of the Isle of Arran, by Prof. Ramsay. See also Prof. Phillips's "Manual of Geology," 1855, p. 503, &c., for some interesting details and sketches of the general geology and plutonic rocks of Arran.

* Some instructive observations, by the Rev. Prof. Haughton, on the composition of some of the Granites of Ireland, illustrated by numerous analyses, and accompanied by remarks on the relative distribution of the several varieties of potash-granites and soda-granites, will be found in the Quarterly Journal of the Geological Society, vol. xii. p. 171, and also in a second Memoir read before the Society in January, 1858.

† See De la Beche's "Geol. Observer," 2nd edit. p. 575, for descriptions and illustrations of these phenomena. Also Phillips's "Manual," p. 508.

rigin than the beds in which they are intruded. Thus the ranite-veins represented in this diagram (*Lign.* 210, *fig.* 1) re newer than the slate-rocks which they penetrate.



LIGN. 210.—INTRUSIVE VEINS OF TRAP, GRANITE, PORPHYRY, &c.

g. 1. Granite-veins (*a*, *a*) traversing schist, Isle of Arran.*
2. Veins of granite (*a*, *a*) traversing schist, themselves crossed by veins of two different kinds of porphyry (*b*, *b*, *b*).
3. Gneiss (*b*, *b*, *b*, *b*) shifted by a granite-vein (*a*, *a*, *a*).
4. Intrusion of trap between layers of sandstone (*a*, *a*), presenting an example of fracture and displacement so small, as to admit of the reädaption of the separated portions.†

Granite-veins traversing other rocks are themselves somemes intersected by intrusions of other melted materials. his is frequently the case in Cornwall and Devon, where umerous granitic and porphyritic dykes (called *elvans* ‡) averse both the granites and the schists (*killas*) of that

* Phillips, Encycl. Metrop., and "Manual," p. 508.
† Dr. Macculloch, Geolog. Trans. and "Western Isles."
‡ See De la Beche's "Report on Cornwall," &c., and that excellent work Physical Geology, the "Geol. Observer," by the same talented author.

district. This sketch (*Lign.* 210, *fig.* 2) represents a mass of schistose rock crossed by granite-veins (*a, a*) in one direction, and again by veins of porphyry (*b, b, b*), which cut through both the schist and the granite. When gneiss is intersected by granite, it becomes shifted, as in this example, in which the granite-veins (*Lign.* 210, *fig.* 3, *a, a, a*) have displaced the laminæ of gneiss (*b, b, b*). Thus, by numerous observations of phenomena of a like nature, it is now clearly established that granite has been ejected during the Silurian, Carboniferous, Jurassic, Cretaceous, and even Tertiary epochs.

Where granite has been erupted in a fluid or softened state among secondary strata, the latter are invariably altered near the line of junction; but when *consolidated* masses of granite have been protruded, no such change is observable. Into the slate-rocks of the Cumbrian chain syenite, porphyry, and greenstone have been injected in a melted state, and now fill up fissures produced during the general movements of those strata; but the central nucleus of crystalline rock exhibits no such appearance.

29. GRANITIC ERUPTIONS.—In the Isle of Arran, the granitic rocks were evidently erupted in a state of fusion, for the slates are penetrated by veins of granite (*Lign.* 210, *fig.* 1); and in some instances are changed into fine-grained mica, or hornblende-slate.

M. Dufrenoy describes granite-veins traversing chalk, in the Pyrenees, which have converted the cretaceous rock into crystalline limestone, and generated in it veins of iron-ore. The following instructive fact is noticed by M. Elie de Beaumont: in the environs of Champoleon, where granite comes in contact with Jurassic limestone, whatever may be the position of the surfaces in contact, the limestone and the granite both become metalliferous near the line of junction, and contain small veins of galena, blende, iron- and copper-pyrites, &c.; and at the same time the secondary rocks are indurated and crystalline, while the granite has undergone a contrary change. Sir C. Lyell mentions a remarkable example of the alteration induced in stratified rocks by intrusions of syenite or granite; near Christiania, in Norway, very dark-coloured limestone is changed into white crystalline marble, and slate into mica-schist. Traces of fossils are not uncommon in some of the schistose rocks, thus unequivocally proving their metamorphic character; as, for instance, the casts of large Trilobites found by Prof. W. B. Rogers in the altered rocks near Boston, U. S. (see page 831).

In Glen Tilt, in Scotland, schist and limestone are superimposed on and traversed by granite, and the latter is intruded among the former rocks, and ramifies into innumerable veins in the most complicated manner, proving its perfect fusion when erupted.*

Granite never occurs truly stratified, but it often assumes a laminar disposition, which may be considered as a modification of concretional structure. A prismatic or cuboidal form is sometimes observable, but this appears to be the result of incipient decomposition, for the fissures become enlarged by exposure to the air and water, and the rock separates into masses resembling piles of masonry, of which the celebrated *Logan* or *Rocking-stones*, and the *Cheese-wring* of Cornwall, are examples.†

In some instances, a tendency to a columnar arrangement is observable, as in the cliffs near the Land's End, in Cornwall. The concretionary felspathic rock of Corsica (*Napoleonite* or "Corsican granite") presents an orbicular structure, in which balls or spheroids of concentric and alternate coats of hornblende and compact felspar, are disseminated with much regularity throughout the mass.

* See the highly valuable Memoir on the Geology of Glen Tilt, by Dr. Macculloch, Geol. Trans. (first series), vol. iii. pp. 259—331.

† *See Appendix B*, on the Logan-stones.

The granites of Devonshire and Cornwall are considered by Sir H. De la Beche to have been protruded after the deposition of the coal-measures of Devon, and antecedently to the Triassic series. "They appear to have been thrown up through points of least resistance, in a line extending from the southern part of Devonshire to the Scilly Isles, part having protruded through the weakest places, and the remainder being concealed beneath. From the Scilly Isles to Dartmoor inclusive, there seems to have been the upthrust of one mass, which found points of less resistance amid the superincumbent accumulations, more in some places than in others. As the masses rose, the edges of the detrital, trappean, and calcareous beds against which they pressed were frequently fractured; and into these fractures the granitic matter was forced, forming veins which can often be traced terminating in fine threads; so that not only was the pressure great, but the fluidity of the igneous rock sufficient to pass into small rents and crevices."*

A group of plutonic rocks, consisting of granite and syenite protruded through overlying schistose and carboniferous deposits, and surrounded at their base by Triassic strata, forms the range of hills known as Charnwood Forest, in Leicestershire. The highest ridge, Bardon Hill, is crested with bare and rugged masses of syenite; and in various quarries opened at the base of the hills, interesting sections are exposed of the relative positions of the crystalline masses and the sedimentary strata. This isolated cluster of hypogene rocks is within a hundred miles of the tertiary deposits of the south-east of England; and at a less distance from the metropolis than any other plutonic region.†

30. METAMORPHISM OF ROCKS.—The transition from

* Memoirs of the Geological Survey of Great Britain, vol. i. p. 228, and "Geol. Observer," p. 563.

† See J. B. Jukes on the Geology of Charnwood Forest, 4to, 1842; and Excursion to Charnwood Forest, Medals of Creation, vol. ii. p. 898.

granite to porphyritic trachyte passes through infinite gradations, but all the modifications appear to be referable to the degree of incandescence of the materials, the circumstances under which they were ejected, and their slow or rapid refrigeration.* An instructive example of the passage of granite into basalt, described by Dr. Hibbert, will illustrate these remarks. In one of the Shetland Isles, a bed of basalt, extending for many miles, is seen in contact with granite. At a little distance from the junction of the rocks, the basalt contains minute particles of quartz, and these become larger and more distinct as they approach the granite: hornblende, felspar, and greenstone (the latter is a homogeneous admixture of hornblende and felspar) next appear; still nearer, the rock consists of felspar, quartz, and hornblende: and at the line of junction felspar and quartz form a mass which requires but the presence of mica to be identical with the granite in which it is insensibly lost.†

Limestone in contact with schist frequently assumes a crystalline structure, as if the same agency, which had converted the clay into schist, had extended its influence to the overlying calcareous beds. In the Isle of Man, interesting examples of this transmutation occur. In some instances the calcareous beds in contact with the fundamental rock of schist are irregular and perfectly crystalline, but change to a stratified disposition and earthy texture in proportion as they are further removed from the schist. In other places the metamorphosis takes place more gradually, each bed of limestone (*Lign.* 211, *a*, *a*, *a*) losing its stratified character, and becoming amorphous and crystalline (*b*) where in contact

* In M. Credner's collection, at Gotha, the Editor was kindly shown by that accomplished geologist a series of Thuringian rock-specimens, in which porphyry was seen to pass into an argillaceous schist full of granules of felspar; also a similar transition from granite to felspathic schist.

† *Edinburgh Journal of Science.*

with the schist (*c*), as is shown in this sketch; the stratified and unstratified rocks ceasing at length to possess any mineralogical distinction. And it is a remarkable and

LIGN. 211.—METAMORPHISM OF LIMESTONE IN CONTACT WITH SCHIST: ISLE OF MAN.

(*Dr. Macculloch's Western Isles.*)

a, Stratified limestone; *b*, Crystalline and amorphous limestone; *c*. Schist.

highly instructive fact, that while in the stratified limestone organic remains occur, they are altogether absent in the crystalline mass.

In the Isle of Anglesea, Carboniferous limestone and shale full of organic remains, may be traced gradually passing into hardened shale, and finally into hornstone, jasper, and analcime-rock containing garnets and copper-ore, a change due an to intrusion of greenstone-porphyry.*

In the Ural Mountains, which form the dividing range that separates the waters of Europe from those of Asia, the effect of metamorphic action is strikingly displayed. Sir Roderick Murchison emphatically remarks, that the crystalline rocks which form the axis of the anticlinal of the

* Prof. Henslow; Transactions of the Philos. Soc. of Cambridge.

Ural chain are for the most part altered Silurian strata. In the short space of a mile, observes Sir Roderick, you may walk upon the edges of the partially altered beds of grit and schist, until you find them converted into amorphous quartz-rock, in contact with highly crystalline greenstone; a rock which is admitted to be of igneous and intrusive character. Coralline limestone is changed into white and green marble. The intense plutonic action which effected the disturbance of the rocks of the Urals has clearly been the cause of the rich mineral productions of those regions, the metallic veins, and the mineralization and metamorphism of the sedimentary strata.*

31. PRECIOUS STONES.†—Connected with the changes to which the metamorphic rocks have been subjected, is the formation of some of those minerals which, from their beauty, splendour, and use as ornaments, are termed precious stones. The *Sapphire* and the *Oriental Ruby*, or red sapphire, which are prized next to the diamond, and almost equal that gem in hardness, are found in trap-rocks; and the common *Corundum*, which is a species of the same mineral, and the *Emerald*, occur in mica-schist. The sapphire and ruby are pure alumina crystallized;‡ and the supposition that they have been formed by intense igneous action, is not only probable, but is rendered almost certain by the experiments of M. Gaudin, who succeeded in producing fictitious rubies, which in every respect resemble the natural gems. These were formed by submitting alumina, with a small quantity of calcined chromate of potash, to the influence of a power-

* Geology of Russia, p. 357, &c.

† Mr. J. R. Jackson's work on Minerals, treating especially of their constitution, mode of occurrence, value, and uses, is full of interest and very instructive.

‡ The sapphire affords, by analysis, 98·5 of alumina, 0·5 of lime, and 1 of oxide of iron; the ruby, 90 of alumina, 7 of silex, and 1·2 of oxide of iron. —*Phillips's Mineralogy.*

ful oxy-hydrogen blowpipe, by which the materials were melted into a crystalline mass, that presented, when cooled, all the characteristics of the ruby.

M. Ebelmen's successful experiments, also, in the production of crystals and gems, by employing boracic acid as a solvent at a high temperature, have an important bearing upon the probable mode of origin of many of the natural mineral products in igneous rocks.*

Garnet is a well-known precious stone, of a rich brownish-red colour, and is generally found in plutonic rocks; like the ruby, it has also been made artificially, by exposing its constituents, silicates of alumina, lime, iron, &c., to intense heat. This experiment throws light on the occurrence of garnets in Anglesea and elsewhere, in shale altered by contact with trap-dykes, though altogether wanting in every other part of the rock; a proof that these crystals have been produced by the effect of heat on those parts of the sedimentary deposits which were most exposed to the influence of the erupted mass.†

The production of such crystalline substances, though effected by intense heat, may probably be intimately connected with the action of electro-chemical currents induced by the high temperature, since M. Bequerel and Mr. Cross have formed without heat, from solutions, by long-continued galvanic action, crystals of quartz, arragonite, carbonates of lime, &c., which the resources of chemistry had failed to yield.‡

* See De la Beche's "Geol. Observer," 2nd edit. p. 578.

† Lyell's Manual, 5th edit. p. 484

‡ "Light, Heat, Electricity, Magnetism, Motion, and Chemical-affinity are all convertible material affections; assuming either as the cause, one of the others will be the effect. These forces, in their varied natural action upon the surface of our planet, are continually altering the nature of its external crust."—*Lecture on the Progress of Physical Science, by W. R. Grove, Esq., F.R.S.*

32. METALLIFEROUS VEINS.—In my description of the fissures observable in consolidated strata, I mentioned that the richest depositories of the metals occur in certain cavities, termed metalliferous veins, which are separations in the continuity of rocks, of a determinate width, but extending indefinitely in length and depth, and more or less filled with metallic and mineral substances of a different nature from that of the masses they traverse.* These natural stores of hidden treasures are not confined to any epoch or formation, nor to any tracts of country; they are, however, most abundant in rocks that have been exposed to great disturbances and intense igneous action, hence their prevalence in the metamorphic and plutonic rocks: but veins of iron, copper, arsenic, silver, and gold also occur in tertiary strata (vol. i. p. 289).

Some veins are evidently fissures of mechanical origin, having been opened by elevatory forces; in many instances they have been filled from beneath by the sublimation of metalliferous matter by heat; and in others from the surface by infiltration, or by various materials deposited by streams, which have flowed into them.† But in some instances the veins are connected, by a gradual mineral transition, with the contiguous rock, and appear to have resulted

* In De la Beche's "Geological Observer," the student will find the subject of mineral veins well illustrated, and philosophically treated. Much valuable information on this subject is also contained in the elementary works on Geology by Phillips and Ansted; and several important papers on veins and the structure of mineral lodes will be found in the Transactions of the Geological Society of Cornwall, and in the Mining Review.

† The filling up of the concretionary veins, and the formation of a great number of minerals which are there met with, whether crystallized or amorphous, appear to admit of explanation by reference to incrusting thermal depositions, and do not necessarily indicate conditions or agents far removed from actual existing causes. See M. de Sanarmont's observations, *Edinb. New Phil. Journ.* 1852, vol. lii. p. 328.

from an electro-chemical separation, or segregation, of certain mineral and metallic particles from the enveloping mass, while it was in a soft or fluid state, and their determination to particular centres. The nature of these veins receives illustration from the nests of spar and other minerals common in masses of trap, and in which there appears to have been no possibility of the introduction of any foreign substance from without.

The vein-stone, vein-stuff, or gangue is frequently formed of several layers of crystalline substances of variable thickness. Thus against each "cheek" or "wall" of a vein or lode, we may find first a coating of blende, then quartz, fluor-spar, blende, baryt-spar, pyrites, baryt-spar, fluor-spar, pyrites, and calc-spar; the two opposite layers of calc-spar either meeting face to face, with irregular cavities, or druses, interposed, or with a middle layer or "rib" of galena. See also p. 696. Sometimes the vein-stone is composed of one material only, such as quartz. Frequently two or more sets of crystallized coatings are observable in a vein, owing to the successive infiltrations or segregations of mineral matter. These may be composed of a similar material throughout; or each series may vary from the others.

From the observations of M. Fournet in the mines of Auvergne, it seems probable that in many instances sulphides of iron, copper, lead, and zinc, sulphate of barytes, and other minerals, have been introduced at different periods, accompanied by new fractures and dislocations of the rocks, and the widening of previous fissures.*

"When describing the successive openings of the veins near Pontgibaud, M. Fournet † points out that deposits of different mineral substances, or modifications of such sub-

* Sir C. Lyell's Anniversary Address, 1837, Proceed. Geol. Soc. vol. ii. p. 498

† Etudes sur les Dépôts Métallifères.

stances, are seen to characterize five of the six successive dislocations which he was enabled to trace; the sixth being marked by the introduction of pebbles and sand,—a continuation of the accumulation which still covers the country in many places, and which is itself covered by the lavas of the extinct volcanos of Louchadière and Pranal." *

The observations and experiments of Mr. R. W. Fox † add great weight to the hypothesis which explains the filling up of metallic veins by electrical agency. M. Bequerel ‡ remarks, that, when a vein is either wholly or partially filled, the transfusion of water from the surrounding rocks would bring electric forces into play, and give rise to decompositions and new combinations of mineral matter. The separation of pure metal from solutions of metallic salts, by galvanic action,—a process familiar to every one, under the name of the *electrotype*,—and from the ore by a modification of the same force, exemplifies the nature of those changes by which native gold, silver, copper, &c. may be produced in the interior of the earth.§

There appear to be certain associations of metallic substances in the veins; ‖ as, for instance, iron and copper, lead and zinc, tin and copper, and probably gold and platinum. The following list shows the geological distribution of a few of the chief metals.

* De la Beche, "Geological Observer," 2nd edit. p. 698, *note*.

† Phil. Transact. 1830, p. 399, &c. See also Mr. R. Hunt's Memoir, On the Influence of Magnetism and Electricity on Crystallization, &c., Mem. Geol. Survey, vol. i.

‡ Edinb. New Phil. Journ. vol. ii. p. 330.

§ M. Bequerel has succeeded, by the permanent action of electrical currents only, in separating the metals of silver, lead, and copper from their ores. The electro-chemical apparatus employed consisted simply of iron, a concentrated solution of sea-salt, and the ore of the metal properly prepared. See notes to Dr. Buckland's Bridgewater Treatise.

‖ In the Edinb. New Phil. Journ. vols. liv. and lv. is a useful and extended digest of A. Breithaupt's work on the Association of Minerals, or their "*Paragenetic Relations*,"—*Die Paragenesis der Mineralien*."

Tin—generally occurs in quartz-veins traversing granite and schist. It has not been discovered in a native state, but is commonly found as an oxide, and rarely as a sulphide. The ores of this metal are of great hardness and specific gravity, and are termed tin-stone. *Wood-tin*, so called from its fibrous structure, and *stream-tin*, are found in the beds of streams and rivulets: they are the alluvial detritus of tin-veins, that existed in rocks now destroyed. The *stanniferous* gravel of Cornwall is the debris of preëxisting rocks traversed by tin-veins, and has been formed in the same manner as the auriferous alluvia of Russia, Australia, and America. The mines of Cornwall are the most productive in Europe, and have been worked from the remotest historical periods. The Tyrians, as early as the time of Moses, imported tin from that district.

Lead.—The ores of this metal are very numerous: and the sulphide of lead, or *galena*, occurs in primary and secondary rocks. In Derbyshire, the principal veins of lead are in the carboniferous limestone.

Copper—is found in primary, secondary, and tertiary rocks, and in modern deposits; it often occurs *native*, that is, in a pure metallic state, sometimes in blocks many tons in weight: its ores, or combinations with other metals and minerals, are very numerous. Cornwall is the principal European repository of this metal.

Gold—exists in granite and quartz-veins traversing metamorphic rocks. The gold found in the mud and sands of rivers has been derived from gold-bearing veins which existed in rocks subsequently broken up and disintegrated: such is the origin of the auriferous sands and gravels of Russia,* which we shall presently describe.

Silver.—This metal is found in crystalline and metamorphic rocks; often native, but generally in ores associated with arsenic, cobalt, &c. Sulphide of silver (a combination of metallic silver and sulphur) is the most common ore of this metal. Masses of pure silver, 200 lbs. in weight, have been found in Norway. The rich Mexican silver- and gold-mines are in porphyritic rocks.

* See the "Geol. Russia and the Ural," vol. i. The gold-diggings of California, Australia, New Zealand, and elsewhere,—their mode of working, general produce, and several large pepites or nuggets,—have of late years been brought before the public in the newspapers and other periodicals, and in numerous special works. The Parliamentary Reports on Australia and the Journal of the Geological Society contain much information on the subject.

Platinum—occurs in South America and the Ural Mountains. This metal combines the lustre of gold and silver with incomparable hardness. A vein has been discovered in metamorphic rocks in the Valley of Drac, in the Department of Isère.

Mercury or *Quicksilver*—is found always liquid when in a metallic state; it is generally obtained from cinnabar, which is a sulphide of mercury, forming beds and veins in gneiss and schist, and in strata of the carboniferous epoch. The mines of Idria in Carniola are the most productive in Europe.

Iron.—The almost universal presence of the ores of iron, and the infinite variety of its combinations, are too well known to require description. Native iron is sometimes found in rocks; but from the rapid oxidation of this metal when exposed to air or moisture, it is seldom met with, except in meteoric stones (vol. i. p. 49).

I will concisely notice a few interesting conditions of some ' these metallic substances.

33. Auriferous Alluvia of Russia.—In the highly ıluable work of Sir R. Murchison and his colleagues, "The eology of Russia," there is an extremely interesting de- ription of the auriferous drift which annually yields a large ıount of gold and some platinum to the Russian government. ıese metals are obtained, by washing, from the old alluvial diluvial deposits, which abound in the bones of mammoths ıd other huge extinct pachyderms (see vol. i. p. 155). The ıld and platinum have evidently been derived from metalli- rous veins that existed in the rocks of the Ural Mountains, efore that chain was elevated above the reach of alluvial tion.

The auriferous shingle, with its sub-angular fragments, so completely sembles the detritus of lakes, and is so unlike the gravel of sea-shores, at, independently of the absence of any marine remains whatever all ong the immediate eastern flank of the Ural Mountains, there can be hesitation in believing that the gold-detritus was accumulated during terrestrial and lacustrine condition of the surface. Previously to the evation of the Urals to their present altitude, they constituted a mode- ately elevated region, which formed the edge of an eastern continent habited by the mammoths and their associates. The extensive areas now covered by auriferous detritus were probably then occupied by lakes, into which were drifted, in the course of ages, the bones of the large extinct mammalia which inhabited the surrounding plains and hills, and the detritus of the rocks and strata. The sudden upheaval of the Ural crest, which has evidently taken place in a comparatively recent period, broke away the barriers of the lakes, and elevated some masses of their shingly bottoms and shores into irregular mounds, which subsequently became desiccated, and now constitute the auriferous alluvia.*

34. Cupreous deposits.—An illustration of a metallic deposit by the effects of chemical action, without the agency of heat, is afforded by a singular formation of copper-ore, which occurs in New Brunswick. In a bed of lignite, covered by a few feet of alluvial soil, and resting on a conglomerate, the precise nature of which is not stated, there is a nearly horizontal layer of green carbonate of copper, about eight inches in thickness. The ore is disseminated through the lignite, in the same manner as metallic ores are usually blended with their accompanying vein-stones. This bed bears a close analogy to the modern cupriferous deposits of Anglesea, and of some parts of Hungary and Spain, where, at the present time, water charged with copper in solution is by the introduction of iron made to precipitate the former metal. From the stratum of lignite occurring with the copper, and the mode in which the latter is interspersed throughout the mass, it appears that the water in which the vegetable matter floated was at the same time saturated with a solution of copper, and that both the organic and mineral substances subsided to the bottom together, and formed the singular compound deposit under consideration; over which, probably at a subsequent period, the alluvial covering was drifted.

Near Perm, in Russia (see page 567), rich cupriferous grits occur, associated with thin seams of coal and abundance of fossil vegetable remains. The copper-ores are frequently

* See "The Geology of Russia," vol. i. pp. 485—487.

found arranged around and in the interstices of the stems and branches of the fossil plants, exhibiting a passage from the common oxide of copper to the grey sulphide, or copper-pyrites; and occasionally to bright green acicular malachite, mixed with crystals of the blue copper-ore.*

In Germany a thin band of hard, black, bituminous, and copper-bearing shales, of Permian age, extends over a wide extent of country, and is well known by the name of the *Kupfer-Schiefer* (see page 566). This thin copper-shale has been worked from time immemorial around the Harz and the Thüringerwald; and still supplies important revenues to Saxony and the neighbouring States.

The beautiful green carbonate of copper, known by the name of *malachite*, has been produced from a cupreous solution by the successive deposition of the metallic carbonate in a stalagmitic form, like the calcareous spar of limestone-caverns.†

35. Transmutation of Metals.—The varied transmutations which metallic substances undergo in their passage from one combination to another—from their condition in the ancient rocks, to that in which they appear in later formations—involve many curious and highly interesting phenomena.

The transmission of iron from great depths to the surface, in a chemical form by means of chalybeate springs, from deposits in which that metal was mechanically diffused, and the formation of bog-iron, and of iron-stone, through the agency of vegetable matter (see p. 766, *note*), are familiar examples of these changes, and have suggested to Mr. Hugh Miller one of his happiest illustrations. "How strange, if the steel axe of the woodman should have once formed part of an ancient forest!—if, after first existing as a solid mass in a primary rock, it should next have come to be diffused as a red pigment in a transition conglomerate (old red

* Geology of Russia, chap. 8.

† Ibid. vol. i. p. 375.

conglomerate, p. 788),—then as a brown oxide in a chalybeate spring,—then as a yellow ochre in a secondary sandstone,—then as a component part in the stems and twigs of a thick forest of arboraceous plants,—then again as an iron-carbonate slowly accumulating at the bottom of a morass of the Coal-measures, then as a layer of indurated bands and nodules of brown ore, underlying a seam of coal,—and then, finally, that it should have been dug out, and smelted, and fashioned, and employed for the purpose of handicraft, and yet occupy, even at this stage, merely a middle place between the transmigrations which have passed and the changes which are yet to come!"*

36. REVIEW OF THE HYPOGENE ROCKS.—Enough has been advanced to convey a general idea of the characters and relations of the hypogene rocks, and of the changes induced on contiguous sedimentary deposits by their influence, when injected or upheaved in an incandescent state.

The traces of stratification—a structure which we have seen is characteristic of aqueous deposition—are evident in the uppermost metamorphic rocks; and there is also a distant analogy to the alternate depositions of secondary beds, in the succession of different mineral masses, as gneiss, mica-schist, quartz-rock, &c. But in the lowermost term of the series, the granite, even these apparent relations to the stratified formations are altogether wanting; and in the amorphous masses, veins, and dykes, we see the effects of long-continued and intense heat, produced under circumstances which have given to the resulting rocks a very peculiar character.

The transmutation of chalk into crystalline marble,—of loose sand into compact sandstone,—of argillaceous slate into porcelain-jasper,—of coal into anthracite,—of shale and mud-stone into slate,—of slate into micaceous schist,—of micaceous schist into gneiss and granite,—of the latter into

* The Old Red Sandstone, p. 250.

trap,—and so forth—together with the characters presented by the mineral products of existing volcanos, prepare the mind to receive without surprise the assertion of an eminent geologist and chemist, M. Fournet; *that all the hypogene rocks are probably sedimentary deposits metamorphosed by igneous action;* * this opinion, however, is but a modification of that long since expressed by our illustrious countryman, Hutton, illustrated by Playfair, and fully elucidated by Lyell.†

There is one striking deduction which M. Fournet has drawn from the mineralogical character of these rocks, namely, that those masses, which, according to our chemical knowledge, would require the most intense and long-continued incandescence for their formation—*i. e.* those in which quartz largely predominates — are precisely those which from their geological position must have been longest exposed to such an agency; hence, in granite the foundation rock, quartz, which is the most infusible and refractory material, largely prevails. The possibility of an earth being converted by intense heat into the hardest and purest crystal was shown in the formation of fictitious rubies (p. 905). To the granite succeed rocks in the exact order of their containing less quartz, and being therefore more easily fusible, —as granite with a large proportion of felspar, porphyry, mica-schist, serpentine, and clay-slate.‡ If we take these phenomena into consideration, together with the facts, previously stated, of the transmutation of one substance into another by the effect of caloric, it appears to me, that in the present state of our knowledge we are warranted in concluding, that all the granite and associated plutonic rocks that are accessible to human observation are nothing more than sedimentary deposits altered by igneous agency.

But from what source were the most ancient granitic

* The general reader will find an interesting account of M. Fournet's theory in Jameson's Edinburgh New Phil, Journal, vol. xxiv. p. 116, &c.

† "Manual of Geology," chap. 35.

‡ Jameson's *Edinburgh Journal*, loc. cit. p. 115.

rocks derived?—whence originated the materials upon which igneous action exerted its influence, and produced those crystalline masses which are the *Ultima Thule* of geological research? Was granite, as Humboldt has supposed, the basis or framework upon which the first aqueous sediments were deposited?—These are questions which we are not in a condition to solve; and it does not appear probable, that vestiges of the first dawn of creation upon the surface of our planet will ever be revealed to mortal eye.

37. ORGANIC REMAINS IN THE METAMORPHIC ROCKS. —I have stated, that with the lowermost of the slaty rocks, or crystalline schists, all traces of organization are lost; but this assertion requires some reservation, for, as an eminent geologist has remarked, "with the exception of granite, probably no rock is known beneath which organic remains may not be found."* Let us here resume the inquiry.

The extent to which the metamorphism of sedimentary rocks changes their lithological characters is variable; and so also is the degree in which the organic remains imbedded in those deposits are obscured by this change. Some of the strata that have suffered from metamorphic agency in the Alps and Andes frequently retain impressions of fossils sufficiently distinct to enable the palæontologist to decide the geological age of these schists and slates; some of which are of secondary, and others even of tertiary age.†

So also many of the much-altered Devonian and Silurian rocks have given up to persevering research abundant fossil relics, in Europe, England, and North America. We may instance M. Bischoff's discovery of Upper Silurian plant-remains in the slaty schists of Mägdesprung (p. 822); Mr. Salter's and Dr. Kinahan's discoveries of fossils in the

* Macculloch's Western Isles, p. 514.

† The German geologists have come to the conclusion that the Glarus-slates (see p. 365) are of eocene age. In the Carinthian Alps there are *black* slates of cretaceous age.

Cambrian grauwacke (p. 837); Mr. Peach's discovery of Lower Silurian fossils in the silicious limestones of Durness (p. 806); and especially Prof. W. Rogers's late discovery of numerous impressions and casts of trilobites in the old rocks near Boston, U. S. (p. 831).

These instances of successful research in metamorphic rocks lead us to hope that other schists, as yet apparently barren of fossils, will in time yield some organic evidence of their geological age. From the researches of Sir R. Murchison,* we now know that great masses of the gneissose and micaceous schists of the North of Scotland are most probably of Lower Silurian age, on account of their immediately overlying (in Sutherlandshire) the fossiliferous limestone and quartzite of Durness (p. 806); and doubtlessly in this, as in other analogous cases, traces of fossils will some day be found in such rocks, which often almost rival in their crystalline character the primordial gneiss and granitic rocks, on which the oldest sedimentary beds of Canada, Scotland, and Scandinavia repose.

From the intense heat to which some of the crystalline and metamorphic rocks have been exposed, we cannot, of course, expect to find in them any organic remains, except possibly such as are formed of materials capable of resisting the effects of that influence. The observations and experiments of the Rev. J. B. Reade have shown, that vegetables possess a structure which is composed of silex, and is indestructible in a common fire (p. 716). In animals, excepting in some of the Protozoa, we seek in vain for an elementary tissue capable of resisting the powerful influence of heat. For it is clear, that, if calcareous skeletons were exposed to intense heat, all traces of organization would be obliterated; and it would therefore be hopeless to expect any indications of animal organisms, except of those that were silicious, in rocks where even the lines of stratification are melted away.

* *Geol. Soc.* Proceed. Feb. 3. 1858.

M. Ehrenberg, to whom we are so greatly indebted for opening this new field of inquiry, has discovered the remains of the minute vegetable organisms known as Diatomaceæ, not only in aqueous, but also in volcanic products. The ferruginous or ochreous film or scum seen on the waters of marshes and of stagnant pools, or at the bottom of ditches, sometimes forming a red or yellowish mass many inches thick, without any consistence, dividing at a touch into minute atoms, and which, when dried, resembles oxide of iron, is found to be wholly composed of the shields or frustules of the *Gallionella ferruginea:* and the formation of bog-iron-ore is supposed to be in a great measure dependent on this source. The semi-opal and the tripoli of the tertiary deposits are wholly composed of fossil remains of this kind; and Ehrenberg distinctly states, that while in the instances above mentioned there cannot be the least doubt of the nature of the organic remains, in the semi-opal of the serpentine of Champigny, and in the precious opal of the porphyry, he has detected bodies so exactly similar that, although at present he hesitates positively to affirm that they are organic, he can scarcely entertain any doubt upon the subject.

As Ehrenberg has also discovered silicious infusorial remains in volcanic ejectamenta, it can be conceived that such indestructible organic atoms may exist even in metamorphic crystalline schists. This branch of palæontological research requires, however, peculiar patience and acumen; and it is to be hoped that the observations of the Rev. J. B. Reade* and Mr. Bryson,† who have found minute bodies resembling Gallionellæ, Naviculæ, &c., in mica-schists, will be followed up with caution and perseverance.

38. Chronology of Mountain-chains. — We have seen that the intrusions of molten rocks have not only altered the chemical nature of the strata through which

* See Appendix C. † Edin. N. Phil. Journ. N. S. vol. i. p. 368.

they were erupted, but have also changed their positions and relations, and produced corresponding modifications in the physical geography of the dry land; having in some instances transformed plains into mountain-peaks, and in others occasioned the subsidence of elevated regions to the bottom of the ocean. As these changes took place at various epochs, separated from each other by periods of repose, sometimes considerable, sometimes brief, it is manifest that the existing mountain-chains are of very different ages. By a careful examination of the phenomena which bear upon this question, the relative antiquity of many of the principal ranges has been determined; or, in other terms, it has been ascertained at what geological epochs the Alps, Pyrenees, Andes, &c. were elevated above the waters.

My observations on this subject must, however, be restricted to an explanation of the mode of induction employed, and a brief notice of some of the results. The positions of the older strata in relation to the protruded plutonic rocks and the newer sedimentary deposits are the principal data by which this problem may be solved; for, as the several stratified rock-masses have been deposited in nearly horizontal positions, it is obvious, that when they are found highly inclined, and in contact with mountain-masses of crystalline or volcanic rocks, the latter must have been protruded *since* the sedimentary were formed, and of course during the primary, secondary, or tertiary periods, as the case may be. On the contrary, if we find other strata in contact with the same masses, but only touching them with their edges, or encircling their base in an unconformable position, it is evident that the mountains must have been elevated before the formation of the latter deposits.

It is by cautious inductions of this kind, that a distinguished savant, M. Elie de Beaumont, has shown,—1 that the mountain-chains of the Erzgebirge, in Saxony, and of the Côte d'Or, in Burgundy, are newer than the Jura limestone, but older than the Greensand and Chalk. 2. That the Pyrenees and Apennines are of about the same age with the chalk-formation. 3. That the western part of the Alps is of later origin than the older tertiary formations, and was raised up after the last of the newer pliocene beds were deposited.

The Caernarvon chain was elevated anterior to the deposition of the mountain-limestone, for the latter wraps round it like a mantle.*

Professor Phillips infers, that when the Grampian Hills sent forth streams loaded with detritus to straits where now the Valleys of the Clyde and Forth meet, the greater part of Europe was beneath the sea. For the Pyrenees and Carpathian Mountains are younger than the Grampians and the Mendip Hills.

That the *sudden* protrusion of such immense masses as the Alps or Pyrenees from the bottom of the ocean must have dislodged vast volumes of water, and created a series of waves high and powerful enough to cause transitory but destructive inundations over such portions of the adjacent dry land as were only a few hundred feet above the level of the sea, cannot be doubted; but, if the elevations were gradual, such effects would take place only in a very slight degree.

39. SYSTEMS OF ELEVATION.—From the facts and observations that have been adduced, it is sufficiently obvious that prodigious masses of granite and other hypogene rocks have been raised into ridges and mountain-chains at various periods, and long after their first formation and subsequent consolidation. In many cases the protrusions are local and of comparatively small extent, at least so far as their distribution on the surface is concerned; for very distant isolated peaks of plutonic matter may have a deep-seated connexion. But in other instances the elevatory force has

* Professor Sedgwick.

embraced a vast area, and entire mountain-chains have been simultaneously and permanently lifted up, and now remain in parallel ranges; the subordinate parts of any one period or system of elevation being in accordance, as to position and direction, with the principal upheaved masses. Admitting the general correctness of these views, it follows that mountain-ridges composed of vertical or highly inclined beds, emerging from beneath horizontal deposits, must have been thrown up previously to the deposition of the latter: and that their upheaval was succeeded by a long period of repose, during which the flanks of the mountains beneath the sea were covered by the horizontal sediments; the latter, elevated above the waters by subsequent movements, now form the fertile plains which surround the base of the Alpine districts.

Professor Sedgwick remarks, that, if we admit that the higher regions of the globe have been raised from the sea by any modification of volcanic force, we must also admit that there have been many successive epochs of extraordinary plutonic energy, separated from each other by long periods of repose.* The sudden formation of mountain-peaks by violent upbursts of subterranean force may be regarded as paroxysmal efforts of the expansive power by whose long-continued and imperceptible action the elevation of continents, and of extensive areas of the bed of the ocean, is gradually effected.†

40. The Caledonian Valley.—The British Islands afford striking illustrations of the long-continued parallelism in the direction of the disturbing forces. The great Caledonian Valley extends through Scotland almost in a straight line, from S. W. to N. E., from near Lismore Island to Fort George in Moray Frith; a distance of more than a hundred

* Anniversary Address to the Geological Society, for 1831.

† See Mr. Bakewell's sagacious commentary on this question, Introduction to Geology, p. 531.

miles. This magnificent glen, with its system of rectilinear lochs or lakes, and friths, has been produced by a wedge-shaped ridge of gneiss having been upheaved in a solid mass, and forced through the stratified deposits which now abut against it in highly inclined positions. That this vast ridge of plutonic matter was in the state of a hard rock when elevated, is inferred from there being no interpolations of volcanic products among the contiguous Devonian strata; and from the latter manifesting no indications of the changes which would have been induced by intense heat. Hence the sharp mountain-ridges and peaks of these Alpine regions, the precipitous glens, the narrow passes, and the deep lochs studded with islands, presenting every variety of combination and contrast of rock, and wood, and water, which constitute the magnificent scenery of the Highlands.

Now, by a reference to a geological map of England and Scotland, it will be seen that the principal mountains or ridges of elevation of these countries extend in a line nearly parallel with the direction of the Caledonian Valley, from the Atlantic to the German Ocean. As, for example, the Grampians, which have thrown up the Devonian strata on their southern flank; the nearly parallel range of the great coal-field of Scotland; the Silurian rocks of the south of Scotland; and successively the principal secondary groups of England. "In all," as Mr. Miller observes, "there is an approximation to parallelism with the Caledonian Valley, affording proof that this was the general direction of the elevatory force, during all the immensely-extended term of its operations, and along the entire length of the Island."*

* The Old Red Sandstone, p. 105. "It is a fact not unworthy of remark, that the profound depths of Loch Ness were affected by the great earthquake of Lisbon in 1755 (p. 843); and that the impulse, true to its ancient direction, drove the waves in long furrows to the north-east and south-west." See Appendix, D.

41. Structure of Ben Nevis.—Though all granitic rocks are of the same general character as to structure, composition, and formation, they belong to different epochs; and, when in juxtaposition, or intercalated with sedimentary beds, their relative age may be determined, as we have previously explained. Even when these aids are wanting, different epochs of eruption are sometimes indicated by variations in the mineral aspect of the rocks; and I will conclude this subject with a short notice of a highly illustrative example.

Ben Nevis, the monarch of the Scottish mountains, is situated on the southern border of the great Caledonian Valley, suddenly rising up in imposing grandeur from the low country, to an altitude of 4370 feet above the level of the sea. The base and lower portion of the mountain are composed of gneiss and mica-schist; above and *within* which is a zone of granite; and *within* the latter, and rising out of it, is a central, naked, rocky prism of porphyry, which is the nucleus, and forms the highest peaks of the mountain.

The inference as to the relative age of these three different masses of plutonic rocks from their order of superposition is the very reverse of that deducible from such an assemblage of sedimentary strata. In the present case the outer or overlying gneiss and mica-schist that envelope the lower region of the mountain are the most ancient; the granite is the next in age, having protruded through and upheaved the gneiss; and the central nucleus of porphyry is the youngest, or last erupted rock, having been forced up through the dome of granite. These three phases of plutonic action may have taken place at different and very distant periods; in like manner as the beds of tuff and scoriæ of Vesuvius or Etna, ejected a thousand years ago, may be upheaved and traversed by the modern eruptions of incandescent lava.

42. RETROSPECT.—I now approach the termination of this argument, and it will be instructive to review the phenomena which have passed before us, in order that we may retain a clear conception of the leading principles and inferences that have been enunciated. I shall, therefore, in the first place, offer a summary of the most important changes which have taken place in the animal and vegetable kingdoms, and in the physical conditions of the earth's surface, during the vast periods which our investigations have embraced; and conclude with a retrospective survey of the effects of vital action in the elaboration of the solid materials of the crust of the globe.

With the view of recalling the principal facts, I now place before you the series of Illustrations employed in these Lectures, that you may perceive at a glance the striking contrast presented by the Faunas and Floras of the respective geological epochs.* In the first stage, traces of the existing species of animated nature were everywhere apparent; and works of human art, with the bones of man and the remains of contemporaneous animals and vegetables, were found in the modern deposits. In the preceding era (the *Tertiary*) many existing species and genera, of plants and animals, were absent. Large terrestrial pachydermata greatly predominated, and the vegetation was principally of a character referable to temperate and intertropical climes; while the seas abounded in fishes, crustaceans, and mollusca, as at the present time.

The next period (the *Cretaceous*) presented a wide ocean, teeming with the general types of marine beings, but of different species and genera to those of the later eras, and

* The reader may realize this idea by referring to the illustrations of these volumes, commencing with the fossil human skeleton (vol. i. pp. 87 and 88), and proceeding from the large mammalia (pp. 153, 168, 175), to the last of the series, the fossils of the palæozoic deposits (pp. 794, 828, and 829).

bearing a large proportion of extinct cephalopodous mollusca. Some algæ represent the marine flora; and drifted trunks and leaves of cycads, conifers, and dicotyledonous trees, and a few reptiles, were the only indications of the dry land and its inhabitants. The delta of a vast river now appeared (the *Wealden*), containing the spoils of an extensive island or continent; and the remains of colossal reptiles, of small mammalia, and of insects, and of extinct tropical plants, marked the era of the country of the Iguanodon.

We were then conducted to other seas (those of the *Oolite* and *Lias*), the waters of which abounded with fishes, molluscs, and zoophytes, and were inhabited by marine reptiles, wholly unlike any that now exist; while the dry land was tenanted by enormous terrestrial and flying reptiles, small marsupial animals, and insects, and possessed a subtropical flora of a peculiar character.

The *Triassic* deposits showed us a somewhat similar group of animals and vegetables. But in the *Permian* strata, though so similar in mineralogical characters to the last, we met with a totally different fauna and flora; and indeed entered upon the *palæozoic* system of life, having passed downwards through the successive periods of the *neozoic* system. The Permian sea was full of life, and the land was clothed with ferns and conifers, and was inhabited by many reptiles, which united the characters of the saurians and the batrachians; and possibly mammals also existed.*

The succeeding era disclosed extensive regions covered by a luxuriant vegetation (the *Carboniferous*); with jungles and forests of arborescent ferns, coniferæ, and gigantic trees related to the existing club-mosses and equisetaceæ; the numerical preponderance of the flowerless plants constituting a botanical character unknown, with but one exception, in modern floras. The land bore sauro-batrachian reptiles and insects; the fresh and brackish waters swarmed with mol-

* According to Emmons; see p. 570.

luscs, crustaceans, and fishes; and the ocean abounded in fishes, mollusca, and zoophytes, of peculiar genera and species. We advanced to other oceans (the *Devonian* and the *Silurian*), the repositories of corals, crinoids, and molluscs; all of the palæozoic types of form. The Devonian waters, too, swarmed with fishes, some of them similar to those of the Carboniferous period; and a few reptiles existed. The Silurian seas were for a long time destitute apparently of fish; but at last a few, similar to those that abounded shortly afterwards, appeared before the Silurian period closed. In the Devonian series we saw abundant relics of terrestrial vegetation, related to that of the Carboniferous lands; nor is some trace of such a flora wanting in the later portion of the Silurian age.

But as we proceeded in a descending order, traces of animal and vegetable existence became less and less manifest, and were at length reduced to worm-marks and a few doubtful sea-weeds; these finally disappeared, and dubious vestiges of infusoria were the last indications of organic life.

43. SUCCESSIVE CHANGES IN THE ORGANIC KINGDOMS. —If we reverse the order of our retrospective survey, and pass in succession from the most ancient to the modern deposits,—from the regions of sterility and plutonic action, to those in which animal and vegetable life were profusely developed,—we obtain the following results:—

En- ul), oda	Fucoids. Lycopodiaceous remains in the uppermost beds.
de- are are o.)	Fucoids, Lycopodiaceæ, Calamitaceæ, Ferns, and Conifers.
ilst nce of	Fucoids, Fungi, Lycopodiaceæ, Calamitaceæ and Equisetaceæ, Ferns, Conifers, Cycads, and some Phanerogamic plants.
but *al*, gns	Fucoids, Lycopodiaceæ, Calamitaceæ, and Equisetaceæ, Ferns, Cycads. and Conifers.
da, ep- .	Fucoids, Equisetaceæ, Conifers, and Cycads. (The last are more abundant than in the Palæozoic ages.)
d- ta s), ro- er- s), tes l), r), n- n- he	Fucoids, Fungi, Lycopodiaceæ, Characeæ, Equisetaceæ, Ferns, Cycads, Palms, Conifers, and Angiospermous plants. (The last were plentiful only in the Cretaceous period.)
of er a- ng d- es o- is he	The numerous families of the Acotyledonous, Monocotyledonous, and Dicotyledonous classes that exist at the present day. (See p. 734.) (The abundance of Angiospermous vegetation characterizes the Tertiary flora, as distinct from that of the Secondary periods.)
er d.	

d to have been made by Birds; and now even Prof. nks that Agassiz's view of their having been made by s occurs in the Dinornis; showing that the presence bove, p. 588.

[To face page 928.

This sketch, afforded by the accompanying table, presents an outline of the most striking changes observable in the succession of organic beings preserved in the respective formations.

In this view, fucoids, annelides, zoophytes, crinoids, crustaceans, and molluscs afford the oldest evidences of organic existence remaining to us. These receive the addition of lycopodiaceous plants on the one hand, and of fishes on the other: both possibly indicating the growing up of a neighbouring shore in the Upper Silurian sea of the British area. In the succeeding periods reptiles and insects appear, with sauroid and other fishes, and an immense development of vegetable forms, particularly of the cryptogamic class. Large reptiles next prevail to an extraordinary degree; and doubtful indications of birds, and a few small mammalia, attest the existence of the higher orders of animals. The vegetable kingdom is greatly modified; palms appear, and plants and trees of the cycadeous and coniferous tribes preponderate. The next remarkable change is in the sudden increase of mammiferous animals, and the reduction of the reptile tribes; the large extinct pachydermata, as the mastodon, mammoth, &c., associated with existing genera and species of other classes of animals, first appear. From this period to the creation of Man, there are no striking general modifications in the various orders of animal and vegetable existence.

Hence, according to our present palæontological knowledge, the first appearance of certain classes and orders of animals was in the following chronological orders:—

Periods.		
Cambrian and Silurian	Invertebrata	Radiaria. Crustacea (Entomostraca). Mollusca.
	Vertebrata. (In the Ludlow rocks only.)	Fishes (Cephalaspides and Placoids).
Devonian . .	Fishes of several families, but all *heterocercal*. *Reptiles* (rare; p. 797).	

PERIODS.	
CARBONIFEROUS	Reptiles, numerous (Batracho-saurians). Land-shell (Nova-Scotia). Insects. Crustaceans, of higher grade than the Entomostraca.
PERMIAN . .	Reptiles (Batracho-saurians and Saurians). Mammals (Chatham Coal-field, North Carolina).
TRIASSIC . . .	Fishes, mostly *homocercal*. Reptiles, abundant (Batracho-saurians, Enaliosaurians, and others). Mammal (Stuttgart).
JURASSIC AND CRETACEOUS	Great Terrestrial Dinosaurians. Pterodactyles. Crocodilian Saurians. Several Mammalia (Pachyderm [Stereognathus], Marsupial, Insectivorous, and Cetacean ?). Birds ? Freshwater Pulmoniferous Mollusca.
TERTIARY . .	Mammalia of all orders, except Man. (The Ruminantia and Proboscidea appeared last.) Birds.
POST-TERTIARY	Man.

It was from this *apparently* successive development of living beings, from the most simple to the most complex organizations, that the geological theory which once prevailed took its rise;* but I scarcely need remark, that the facts we have stated warrant no such inference: for many of the fossil animals which appear in the most ancient or earliest strata belong to orders having a highly developed organization. Nor does the vegetation of those remote periods lend any real support to such a hypothesis; coniferæ and the most perfectly organized of the cryptogamic class forming the flora of, at least, the Upper Palæozoic period.

44. GEOLOGICAL EFFECTS OF DYNAMICAL AND CHEMICAL ACTION.—The physical changes that have taken place on the earth's surface are in perfect harmony with the modifications observable in animated nature; for the laws of mechanical and chemical action are inseparably connected

* See Organic Remains of a Former World, vol. iii. p. 449.

h those which govern vital phenomena; and we have ontrovertible evidence, that, throughout the vast periods r which our observations have extended, the same causes e operated, and the same effects followed. Thus, heat and d, drought and moisture, and other meteoric influences, e denuded the loftiest peaks,—rivulets and torrents have ded the sides of the mountain-chains,—streams and rivers e channelled the plains and transported the spoils of the d into the bed of the ocean,—the waves of the sea have ited its shores, and destroyed the cliffs and rocks which osed their progress,—silt has been changed into clay,— careous mud into limestone,—sand into sandstone,— bles and shingle into conglomerates and breccia,—and mal and vegetable remains have been imbedded, and added the mineral accumulations of the past ages of our planet. Beneath the surface, the action of electro-chemical forces been alike unintermitting,—vegetable matter has been verted into bitumen, coal, amber, and the diamond,— th into crystals,—limestone into marble,—clay into slate, nd sedimentary into crystalline masses traversed by me- iferous veins; the volcano has poured forth its rivers of lten rock,—the earthquake rent the solid crust of the be,—beds of seas have been elevated into mountains,— sidences of the land and irruptions of the ocean have en place,—and the destructive and conservative influences caloric and of water have been constantly exerted; the ses of action have alone differed in duration and intensity.

"Ages have roll'd their course, and Time grown grey.
The earth has gather'd to her womb again,
And yet again, the myriads that were born
Of her uncounted, unremember'd tribes.
The seas have changed their beds,—th' eternal hills
Have stoop'd with age,—the solid continents
Have left their place,—and Man's imperial works,
The toil, pride, strength of kingdoms, which had flung
Their haughty honours in the face of heaven,
As if immortal, have been swept away." HENRY WARE.

45. STRATA COMPOSED OF ORGANIC REMAINS.—In a previous discourse (Lect. VI.) I dwelt upon the highly interesting subject of the elaboration of calcareous and silicious strata from gaseous and fluid elements by vital action, and the formation of islands and continents by the agency of countless myriads of living instruments. Let us for a moment consider how far the present mineral constituents of the earth's crust have been derived from organized beings.

The strata of vegetable origin consist of peat, of forests ingulfed by subsidences of the land, or imbedded in the silt and mud of rivers and deltas, or in the bed of the ocean, —of the lignite and brown-coal of the tertiary deposits,—of the coals and shales of the carboniferous strata,—of the fucoid-beds of various ages,—and of the silicified and calcified trunks of trees in the tertiary, secondary, and upper palæozoic formations.

But the strata which consist wholly, or in a great measure, of animal exuviæ are so numerous, and of such prodigious extent, that the interrogation of the poet may be reiterated by the philosopher—

"Where is the dust that has not been alive?" YOUNG.

For there is not an atom in the crust of the globe that may not have passed through the complex and marvellous laboratory of life!

Thus we find that all the varied orders of animals, from the Animalcules up to Man, have contributed, more or less, by their organic remains, to swell the amount of the solid crust of the earth. The following table presents a concise view of some of the most obvious examples of this indisputable fact:—

ROCKS COMPOSED WHOLLY OR PARTLY OF ANIMAL REMAINS.

Strata.	Prevailing Organic Remains.	Formations.
Graptolite-schists	Graptolites	Llandeilo rocks
Trinucleus-shales	Trilobites	Caradoc rocks
Pentamerus-rock	Pentamerus lens, &c.	Llandovery rocks
Dudley-limestone	Corals, brachiopods, bryozoa, crinoids, &c.	Wenlock rocks

Strata.	Prevailing Organic Remains.	Formations.
Gothland-limestone	Beyrichiæ, brachiopods, corals, &c.	Wenlock rocks
Navicula-band . .	Athyris navicula	Ludlow rocks
Bone-bed	Coprolites, fish-bones, &c. .	Ludlow rocks
Cephalaspis-beds .	Fish-remains in nodular concretions	Old Red
Caithness-flags . .	Fish-remains and bitumen	Old Red
Devon-marbles . .	Corals with shells and crinoids	Devonian
Calceola-schist . .	Calceola sandalina and other shells	Devonian
Clymenia-limestone .	Clymenia, goniatites, with other shells, and trilobites	Devonian
Cypridina-schist . .	Minute entomostraca, shells, plants, &c. . .	Devonian
Coral marble . . .	Corals, brachiopods, &c. .	Mountain-limestone
Encrinital marble and shales . . .	Crinoids, brachiopods, &c.	Mountain-limestone
Shell-limestone . .	Brachiopods, foraminifera, &c.	Mountain-limestone
Fusulina-rock . .	Fusulina cylindrica . . .	Mountain-limestone
Fish-beds	Teeth and spines of fish, with shells and corals .	Mountain-limestone
Mussel-banas . . .	Freshwater shells, such as anthracosiæ, &c.	Coal-measures
Ironstone-nodules .	Limuli, insects, and shells	Coal-measures
Fish-shales . . .	Palæoniscus, &c.	Coal-measures
Zechstein	Foraminifera, entomostraca, bryozoa, corals, and shells	Permian
Muschelkalk or shell-limestone . . .	Shells, crinoids, &c. . . .	Trias
Bone-bed	Bones, teeth, and coprolites of fishes, reptiles, and mammals (rare) . . .	Trias
Ammonite-limestone and Ammonite-shale .	Ammonites	Lias
Lias-rock	Shells and crinoids, with bones of reptiles and fishes	Lias

Strata.	Prevailing Organic Remains.	Formations.
Gryphite limestone	Gryphææ and other shells	Lias
Cephalopoda-bed	Remains of ammonites and belemnites, with fish-remains	Oolite
Shelly limestone	Terebratulæ and other shells	Oolite
Stonesfield-oolite	Shells, reptiles, fishes, and insects	Oolite
Caen-stone and Bath-stone	Shells, corals, crinoids, reptiles, and fishes	Oolite
Forest-marble	Debris of shells, echinoderms, &c.	Oolite
Kelloways-rock	Ammonites and other shells	Oolite
Coral-rag	Corals, shells, &c.	Oolite
Nerinæa-limestone	Nerinææ and other shells	Oolite
Portland-stone	Terebræ, trigoniæ, ammonites, and other shells	Oolite
Chert and flint	Sponges, &c.	Oolite
Corbula-beds	Corbulæ and other shells	Purbeck
Cinder-bed	Ostræa distorta	Purbeck
Purbeck-marble	Paludinæ and cypridæ	Purbeck
Sussex-marble	Paludinæ and cypridæ	Wealden
Tilgate-stone (some beds)	Bones of reptiles and fishes, and freshwater-shells	Wealden
Lobster-beds	Meyeria vectensis	Lower-greensand
Kentish rag	Terebratulæ and other shells	Lower-greensand
Oyster-beds	Exogyræ, plicatulæ, &c.	Lower-greensand
Farringdon gravel	Sponges, bryozoa, shells, echinoderms, &c.	Lower-greensand
Ammonite-bed	Fragmentary ammonites, with other shells, and crustaceans, wood, &c.	Gault
Chert and flint	Sponges, shells, &c.	Upper-greensand
Greensand	Casts of chambers of foraminifera	Upper-greensand
Hippurite-limestone	Hippurites, radiolites, and other shells	Chalk
White-chalk	Sponges, foraminifera, bryozoa, echinoderms, crustacea, shells, fishes, and some reptiles	Chalk
Flint	Sponges, &c.	Chalk

Strata.	Prevailing Organic Remains.	Formations.
Maestricht-chalk .	Sponges, foraminifera, corals, bryozoa, echinoderms, crustacea, shells, fishes, and reptiles . .	Chalk
Faxoe-chalk . . .	Bryozoa, shells, &c. . . .	Chalk
Woolwich shell-bed .	Melania, cyrenæ, and other shells	Eocene
Septaria of the London clay . .	Remains of nautili or other shells, of fishes, or of mammals, enclosed in concretionary nodules .	Eocene
Nummulite-rock . .	Nummulites and other foraminifera, with shells, fish-remains, &c. . . .	Eocene
Alveolina-rock . .	Alveolinæ and other foraminifera	Eocene
Calcaire-grossier . .	Foraminifera, bryozoa, and shells	Eocene
Gypsum-beds of Montmartre . .	Bones of mammalia, birds, &c.	Eocene
Indusial limestone of Auvergne . .	Cases of phryganeæ, with freshwater shells . . .	Eocene
Fish-beds of Monte Bolca	Fishes	Eocene
Œningen-beds . .	Mammals, reptiles, fishes, insects, &c.	Eocene
Paludina-beds of Headon Hill . .	Paludinæ, &c.	Eocene
Falunian beds of Touraine, &c. .	Foraminifera, bryozoa, echinoderms, shells, fishes, &c.	Miocene
Subhimalayan beds .	Bones of mammalia, reptilia, &c.	Miocene
Suffolk crag . . .	Sponges, bryozoa, crustacea, echinoderms, molluscs, &c.	Pliocene
Bone-breccia . . .	Mammalia and land-shells .	Pliocene
Bermuda-limestone	Corallines, corals, serpulæ, shells, crustaceans, &c. .	Recent
Guadaloupe - limestone	Human bones, land-shells, &c., in a debris of corals and shells	Recent

This list might be enlarged to a much greater extent, for I have omitted numerous strata in which animal remains largely predominate, such as the lingula-flags, delthyris-shale, pentremite-limestones, and the annelide-sandstones of Cambrian, Silurian, and Carboniferous age; and in the tertiary and modern periods every order of animated nature is found to have contributed, more or less largely, to the sedimentary deposits; the bones of Man appearing only in the most recent accumulations; and, by the geological causes now in action, not only the remains of the existing orders of animals and vegetables, but also works of human art, are daily added to the solid crust of the globe.

46. General Inferences.—Restricting ourselves within the bounds of legitimate induction, and forbearing to speculate on those points which rest on insufficient or questionable data, we may venture to draw some general inferences as to the varying physical conditions of the surface of our planet, and of animal and vegetable life, throughout the immense periods contemplated by geology.

From the remotest epoch in the earth's history recognisable by man, to the present time, we have seen that the mechanical and chemical laws which govern inorganic matter have undergone no change. The wasting away of the solid rocks by water, and the subsequent deposition and consolidation of the detritus in strata, and their metamorphism by high temperature,—the subsidence of the dry land beneath the sea, and the elevation of areas of the ocean-bed above the waters, and the formation of new islands and continents,—the decomposition of animal and vegetable substances on the surface, and their conversion into stone or coal, under circumstances in which the gaseous principles were confined,—the transmutation of mud and sand into rock, and of earthy minerals into crystals,—these physical changes have been constantly going on, under the influence of those fixed and immutable laws established by Divine

Providence for the maintenance and renovation of the material Universe.

And, although among the sentient beings which have from time to time inhabited the earth we discover at successive periods the appearance of new forms, which flourished awhile and then passed away, while other modifications of life sprung up, and after the lapse of ages in their turn were annihilated; yet the laws which governed their appearance and extinction were evidently in perfect harmony with those which regulate inorganic matter. Every species was especially adapted to some peculiar state of the earth at the period of its development; and, when the physical conditions changed, and were no longer favourable for the continuance of that type of organization, it became extinct. The creation of Man, and the establishment of the present order of things, which we are taught, both by Revelation and by natural records, took place but a few thousand years ago, are events beyond the speculations of Geology.

It follows from what has been advanced, that both animate and inanimate nature, linked together by indissoluble ties of mutual adaption, have been governed by the same mechanical, chemical, and vital laws, from the earliest geological epochs to the present time; and that the absence of the fossil remains of whole orders of animals in the palæozoic ages, although, perhaps, in some measure, attributable to the feeble development of those types of being, may have been occasioned by the obliteration of their remains in the rocks, from the subsequent effects of high temperature: at the same time it must be borne in mind that we are examining the beds of ancient oceans, and may not yet have explored those parts of the old sea-beds in which the spoils of the land are concealed.

47. The Ancient World.—With regard to the surface of the earth in the ancient periods comprehended in our survey, there can be little doubt that its physical geography

presented the same general features as in later times; and that then, as now, the land was diversified by hills and dales, mountains and glens, volcanic peaks, elevated regions of perpetual snow, and vast areas of eternal ice,—sterile and sandy deserts, and fertile alluvial plains, irrigated by streams and rivers; the only important discrepancy being the high climatorial temperature that prevailed over extensive areas at certain epochs, and the corresponding modifications in the organic kingdoms. (See above, pp. 772, &c.) But even the most remarkable anomalies in the terrestrial faunas and floras of the palæozoic ages are not without a parallel at the present time.

Thus New Zealand with its peculiar flora,* characterized by the predominance of ferns, club-mosses, &c., to the almost entire exclusion of the graminaceous tribes,—and its mammalian fauna, consisting of but two very small species of quadrupeds (p. 757),—and the bones of recently extinct struthious birds,—presents a general correspondence with the lands of the Carboniferous and Permian periods.† Australia

* See Medals of Creation, vol. i. p. 210.

† In a general retrospective view of this kind, the minor subdivisions or formations must, of course, be disregarded; and while on this subject, I would direct attention to the following remarks of Mr. Leonard Horner in his Presidential Address to the Geological Society, 1847:—

"By whatever names we designate geological periods, there appears to exist no clearly defined boundaries between them in reference to the whole earth: such a marked line may be seen in particular localities, but every year's experience, and our more intimate acquaintance with the phenomena exhibited in different countries, and with the distribution, structure, and habits of animals and vegetables, teach us that there is a blending, a gradual and insensible passage from the lowest to the highest sedimentary strata, particularly in respect of fossil remains. The terms we employ to designate formations can only be considered as expressing the general predominance of certain characters, to be used provisionally, as a convenient mode of classifying the facts we collect together, whilst that knowledge is accumulating which, in after-ages, will unravel the complicated changes that belong to the successive periods into which the history of the structure of the whole earth may be and Van Diemen's Land possess a flora equally peculiar and extraordinary, and a fauna unlike that of any other part of the world, including some of the most anomalous of existing forms, as, for example, that marvellous creature the Ornithorhyncus. These countries, in the abundance and variety of the Cycadaceæ, Araucariæ, &c.,—in the marsupial character of the great proportion of the mammalia,—and in the terebratulæ and trigoniæ, and the cestraciont fishes, which swarm in the seas that wash their shores, approximate in their organic relations more nearly to those ancient lands of which the triassic and jurassic beds, and especially the Stonesfield-oolite, are the debris (p. 506), than to any of the present regions of the earth. And lastly, we have a reflected image, as it were, of the Age of Reptiles of the Secondary periods in the exclusively reptilian character of the quadrupeds of the Galapagos Islands; one species of mouse being the only indigenous mammal.*

"This Archipelago," observes Mr. Darwin, "is a little world within itself: most of the organic productions are aboriginal creations, found nowhere else. Seeing every height crowned with its crater, and the boundaries of most of the lava-streams still distinct, we are led to believe that within a period geologically recent, the unbroken ocean was here spread out. Hence, both in time and space, we seem to be brought somewhat near to that great fact—that mystery of mysteries,—the first appearance of new beings on this earth."

These Islands swarm with herbivorous marine reptiles, allied to the Iguanidæ, which are known in no other part of the world, and they are as completely distinct from all

divided." See also Mr. Hamilton's remarks on the same subject, at the conclusion of his Anniversary Address to the Geological Society, 1855.

* The Galapagos Archipelago is a group of volcanic islands situated under the Equator, and between five and six hundred miles westward of the American coast. See Mr. Darwin's "Journal of a Voyage round the *World*," *chap.* xvii.

other existing reptiles, as are the extinct Iguanodon and Megalosaurus. The flora,* too, contains more than a hundred plants unknown elsewhere. There is not a fauna or flora in any of the ancient geological periods that presents greater anomalies.†

The organic relations between the countries above mentioned and their geological analogues, may be thus expressed:—

Modern Period.	Primary and Secondary Periods.
New Zealand .	Countries of the *Carboniferous* and *Permian periods*, as indicated by fossil remains.
Australia . .	The lands whence the *Triassic* and *Jurassic* strata were derived.
The Galapagos Archipelago	The Country of the *Iguanodon*, and the regions that supplied the detritus that formed the fluvio-marine strata of the upper secondary deposits.

In this point of view the Country of the Iguanodon and the Age of Reptiles may be considered as merely disclosing exaggerated effects of the organic law which imparted to the fauna of the Galapagos Islands its reptilian character.

If the ancient philosophers, ere the discoveries of Columbus had opened the New World to the European mind, had found in a fossil state such collocations of animals and plants as are presented by New Zealand, Australia, and the Galapagos Islands, how impossible it would have been for them, by any comparison with existing nature within their circumscribed geographical boundary, to have imagined that such assemblages of animated beings could exist contemporaneously with themselves. In fact, the present geo-

* An enumeration of the plants of the Galapagos Archipelago, by Dr. J. D. Hooker, is published in the Linnæan Transactions, vol. xxi. for 1847, page 163; and by the same author "On the Vegetation of the Galapagos Archipelago," *op. cit.* p. 235. Out of 253 species of plants, 123 species are unknown in any other part of the world.

† See Appendix E.

graphical distribution of animals and plants affords as many exceptions to the general rule of climatorial influence, in the relative number and importance of different orders of animals and vegetables, as are to be found in the vestiges of an earlier world.*

If we define on a map of the globe those areas of which the geological structure is known from actual observation, we shall at once perceive how small a proportion of the earth's crust has been examined by the scientific observer; how large a part of the surface above the water is concealed by perpetual ice and snow, and is otherwise inaccessible to philosophical research; and that three-fifths of the entire surface of our planet are buried beneath the waves. These facts are highly suggestive:—they teach us that, notwithstanding the immense accumulation of observations made in all parts of the earth, the data hitherto obtained are insufficient to afford a true picture of the full development of organic life, as it existed in the most ancient periods.

In considering these questions, it must too be remarked, that, notwithstanding the differences in the general physiognomy of the earliest and latest faunas, there are certain types common to both. Thus, though Orthoceratites, Lituites, Goniatites, &c., represent the cephalopodous molluscs in the palæozoic seas, yet these are associated with true Nautili; in like manner, with the extinct Brachiopoda, the Spiriferi, Leptænæ, &c., are found species of the still existing genera of Terebratula, Crania, and Lingula. So also, in the tertiary period, existing genera of mammalia and of terrestrial reptiles were contemporaneously inhabitants of the land with the extinct Mastodons and other Pachyderms, and the colossal Tortoises, &c. From these

* See Berghaus's and Johnston's Physical Atlas; and the ingenious maps of the Geographical Distribution of existing Animals and Plants, in the delightful work of that accomplished authoress, Miss Rosina *Zornlin, entitled Researches* in Physical Geography, or the Earth as it is.

considerations we may infer, that throughout all geological time the changes on the earth's surface have been subservient to the same physical and organic laws; and that the paroxysmal terrestrial disturbances, though apparently in the earlier ages involving larger areas, and operating with greater violence, than the volcanic eruptions and earthquakes of later periods, did not affect the established order of organic life upon the surface of the globe; and we may also conclude, that throughout the innumerable ages indicated by the sedimentary formations, there was at no period a greater anomaly in the assemblages of animals and vegetables on particular regions than exists at the present time.*

48. COROLLARY.—Thus the general result of our inquiries into the ancient condition of the earth proves that the changes produced by mechanical, chemical, and vital agency, whether on the surface or in the interior, have been the same throughout all the periods revealed by Geology; and, as like causes must produce like effects, will continue so long as the present material system shall endure.

Hence, deposits now in progress may subside to the innermost regions of the globe, and from exposure to intense heat, under great pressure, all traces of sedimentary origin may be obliterated; and at some future period these metamorphosed rocks may be elevated above the surface, and appear as peaks of granite, or as crystalline mountain-chains, rising from beneath strata teeming with organic remains.

I cannot, therefore, concur in the generally received opinion, that in the most ancient granite accessible to human observation, we see the primeval framework of our globe—

* Hence the so-called Picturesque Sketches of Creation,—the Ancient Worlds,—the Vestiges of Creation,—the Romance of Geology,—and other works of a like nature, are in relation to the philosophy of Geology what the historical novels and romances are to History—medleys of facts and fictions.

the consolidated crust, formed on the surface of a cooling planet, and subsequently broken up by the subsidences and contractions induced by continued refrigeration. The only legitimate inference in the present state of our knowledge appears to be this,—that, as at a certain depth the beds of mineral matter, whether of alluvial or of volcanic origin, may become so entirely changed in structure and composition as to afford no certain data of their original nature, therefore, for aught we know to the contrary, this world may have been teeming with life innumerable ages ere the formation of the most ancient granitic rocks of which we can take cognizance.

49. Final Effects.—In fine, Geology does not reveal to us the first creation of animated beings; it does not afford any physical evidence of a beginning; it does not warrant the attempt to explain the miraculous interpositions of Providence by the operation of natural laws; but it unfolds to us a succession of events, each so vast as to be beyond our finite comprehension, yet the last as evidently foreseen as the first. It instructs us "*that we are placed in the middle of a scheme,—not a fixed, but a progressive one,—every way incomprehensible—incomprehensible in a measure equally with respect to what has been, what now is, and what shall be hereafter.*" *

This new volume of Natural Religion which Geology has supplied has been so ably illustrated by the late Dean of Westminster,† that we need not dwell on the evident adaptation of the successive tribes of living beings, through indefinite periods, to the varying physical conditions of the earth, and by which its surface was ultimately fitted for the abode of the human race. Thus the infusoria lived and died in countless myriads, and produced the tripoli and the opal; river-snails and marine mollusks secreted the marbles, and coral-polypes the limestones, with which we construct our

* *Bishop Butler.* † Bridgewater Treatise.

edifices and ornament our temples and palaces; and herb, plant, and tree have been converted either into a material to enrich the soil, or changed into a combustible mineral, to serve as a fuel in after-ages, when such a substance became indispensable to the necessities and luxuries of civilized man. Hence a new interest has been thrown around every grain of sand, and every blade of grass; and the pebble rejected by the Divine, as affording no evidence of design, becomes in the hands of the Geologist a striking proof of Infinite Wisdom.*

But ought we to rest content in the assumption that all these wonderful manifestations of Creative Intelligence were solely intended to contribute to our physical necessities and gratifications?—Say, rather, that this marvellous display of beauty, power, and goodness was designed to fill the soul with high and holy thoughts, to call forth the exercise of our intellectual powers, to excite in us those ardent and lofty aspirations after truth and knowledge, which elevate the mind above the sordid and petty concerns of life, and give us a foretaste of that high destiny which we are permitted to hope will be our portion hereafter!

50. CONCLUDING REMARKS.—Having thus endeavoured to interpret the natural records of the earth's physical history, and traced the succession of geological periods, each embracing indefinite ages of long duration, and the mutations in the organic kingdoms of nature coincident with the varying conditions of the lands and waters—mutations governed by laws with which we are but very imperfectly acquainted,—let us finally contemplate the relations of our planet to the innumerable worlds around us. For, while Astronomy suggests that our solar system once existed as a diffused mass of vapour or nebulosity, which, passing through

* Paley. This remark alludes to the celebrated argument of this distinguished author, on a watch and a stone, in the first page of his Treatise on Natural Theology.

ℨessive phases of condensation, at length separated into
ntral luminary with its attendant planets and satellites
p. 41); she also instructs us, that this system is but an
nsiderable cluster of orbs in regard to the assemblage of
s to which it belongs, and of which the *Milky-way* is,
were, a girdle, our system being placed in the outer and
stellular part of the zone.*

ut the astounding thought, that all our visible Universe
ut an aggregation, a single group of suns and planets,
ch to the inhabitants of the remote regions that can be
inguished only by our telescopes would seem but a mere
inous spot, like one which lies near the outermost range
bservation, and appears to be a fac-simile of our own,
mpresses the mind with the most intense feelings of
, of humility, and of adoration of that Supreme Being,
vhom worlds, and suns, and systems are but as the sand
the sea-shore!

——— "Awake, my soul,
And meditate the wonder! Countless suns
Blaze round thee, leading forth their countless worlds!
Worlds in whose bosoms living things rejoice,
And drink the bliss of being from the fount
Of all-pervading Love! What mind can know,
What tongue can utter all their multitudes,
Thus numberless in numberless abodes?
Known but to thee, blest Father! Thine they are,
Thy children, and thy care,—and none o'erlooked
Of Thee!" WARE.

gain, when conducted by our investigations to the
sible Universe beneath us, the *Milky-way* and the *Fixed-*
s of animal and vegetable life, which the microscope
als to us, we are alike overpowered by the contemplation
e minutest, as of the mightiest, of His works! And if,
n eminent philosopher has observed, our planetary

* See Whewell's Bridgewater Treatise.

system was gradually evolved from a primeval condition of matter, and contained within itself the elements of each subsequent change, still we know, that every physical phenomenon which has taken place, from first to last, has emanated from the immediate will of the Deity.

VALEDICTION.

With these remarks I take farewell of the reader who has accompanied me through this attempt to combine a general view of geological phenomena with a familiar exposition of the inductions by which the leading principles of the science have been established. And, if I have succeeded in explaining in a satisfactory manner how, by laborious and patient investigation, and the successful application of other branches of Natural Philosophy, the "*Wonders of Geology*" have been revealed,—if I have removed from but one intelligent mind any prejudice against scientific inquiries, which may have been excited by those who have neither the relish nor the capacity for philosophical pursuits,—if I have been so fortunate as to kindle in the hearts of others that intense desire for the acquisition of natural knowledge which I feel in my own,—or have illumined the mental vision with that intellectual light which, once kindled, can never be extinguished, and which reveals to the soul the beauty, and wisdom, and harmony of the works of the Eternal, I shall indeed rejoice, for then my exertions will not have been in vain. And, although my name may be soon forgotten, and all record of my labours be effaced, yet the influence of that knowledge, however feeble it may be, which has emanated from my researches, will endure for ever, and, by conducting to new and inexhaustible fields of inquiry, prove a never-failing source of the most pure and elevated gratification.

For it is the peculiar charm and privilege of Natural Philosophy, that it

——— "Can so inform
The mind that is within us,—so impress
With quietness and beauty,—and so feed
With lofty thoughts,—that neither evil tongues,
Rash judgments, nor the sneers of selfish men,
Nor greetings where no kindness is, nor all
The dreary intercourse of common life,
Can e'er prevail against us, or disturb
Our cheerful faith, that all which we behold
Is full of blessings!" WORDSWORTH.

But transcendent as are the privileges which science confers, the true philosopher feels, with the deepest humiliation, that it is neither in the acquisition of knowledge, nor in the perception of the true and of the beautiful,—even were that perceptive knowledge exalted infinitely,—that human happiness can find a resting-place, or the cravings of the immortal mind be satisfied. Every step leads on the impatient inquirer to one beyond itself. "The nicest mechanical arrangement of the particles of matter does but compel us to contemplate those subtler agents by whose action magnetic relations and chemical affinities are next developed. Exhaust their range, and still there is palpably beyond them the mystery of the vital powers. Follow that to its highest source, and yet we have but reached the first limits of those mightier energies, of reason, conscience, and volition, of which we feel within ourselves the living action. And here, where the darkness which may be felt presses most heavily upon the inquiring soul,—here in seeking to know the Cause of causes,—here alone can there be any repose for the immortal spirit. Only on HIM who made him, can Man rest at last the burden of his awful being!"

* Bishop Wilberforce. Sermon preached before the University of Oxford, *June 27, 1 47.*

APPENDIX TO VOL. II.

SUPPLEMENTARY NOTES.

A. *Page* 883.—The subject of the origin of Crystals, as indicated by the nature of their enclosed cavities, and as bearing on the formation of granite, is of so great an interest that the following abstract of Mr. Sorby's paper (read before the Geological Society, Dec. 2, 1857), "On some peculiarities in the Microscopical Structure of Crystals, applicable to the determination of the Aqueous or Igneous Origin of Minerals and Rocks," is here given.

In this paper the author showed, that, when artificial crystals are examined with the microscope, it is seen that they have often caught up and enclosed within their solid substance portions of the material surrounding them at the time when they were being formed. Thus, if they are produced by sublimation, small portions of air or vapour are caught up, so as to form apparently empty cavities; or if they are deposited from solution in water, small quantities of water are enclosed, so as to form *fluid-cavities*. In a similar manner, if crystals are formed from a state of igneous fusion, crystallizing out from a fused-stone solvent, portions of this fused stone become entangled, which, on cooling, remain in a glassy condition, or become stony, so as to produce what may be called *glass-* or *stone-cavities*. All these kinds of cavities can readily be seen with suitable magnifying powers, and distinguished from each other by various definite peculiarities.

From these and other facts, the following conclusions were deduced:—

1. Crystals containing only cavities with water were formed from olution.

2. Crystals containing only stone- or glass-cavities were formed from a state of igneous fusion.

3. Crystals containing both water- and stone- or glass-cavities were formed, under great pressure, by the combined influence of highly heated water and melted rock.

4. That the amount of water present in the cavities may, in some cases, be employed to deduce the temperature at which the crystals were formed.

5. Crystals containing only empty cavities were formed by sublimation, unless the cavities are fluid-cavities that have lost their fluid, or are bubbles due to fusion.

6. Crystals containing few cavities were formed slowly, in comparison with those of the same material that contain many.

7. Crystals that contain no cavities were formed very slowly, or by the cooling from fusion of a pure, homogeneous substance.

Applying these general principles to the study of natural crystalline minerals and rocks, it was shown that the fluid-cavities in rock-salt,—in the calcareous spar of modern tufaceous deposits, of veins, and of ordinary limestone,—and in the gypsum of gypseous marls, indicate that these minerals were formed by deposition from solution in water at a temperature not materially different from the ordinary. The same conclusions apply to a number of other minerals in veins in various rocks, and to many zeolites. The constituent minerals of mica-schist and the associated rocks contain many fluid-cavities, indicating that they were metamorphosed by the action of heated water, and not by mere dry heat and partial fusion.

The structure of the minerals in erupted lava proves that they were deposited from a mass in the state of igneous fusion, like the crystals in the slags of furnaces; but, in some of those found in blocks ejected from volcanos (for example, in nepheline and meionite), there are, besides stone- and glass-cavities, many containing water, the relative amount of which indicates that they were formed, under great pressure, at a dull red heat, when both liquid water and melted rock were present. The fluid-cavities in these aqueo-igneous minerals very generally contain minute crystals, as if they had been deposited on cooling from solution in the highly heated water. The minerals in trappean rocks have also such a structure as proves them to be of genuine igneous origin, but they have been mualtered by the subsequent action of water, and many minerals formed in the minute cavities by deposition from solution in water.

The quartz of quartz-veins has a structure proving that it has been rapidly deposited from solution in water: and in some instances the relative amount of water in the fluid-cavities indicates that the heat was considerable. In one good case the temperature thus deduced was 165° C. (329° F.); and apparently, when the heat was still greater, mica and tinstone were deposited, and in some cases probably even felspar. There is then, as has been argued by M. Elie de Beaumont, a gradual passage from quartz-veins to those of granite, and to granite itself; and there is no such distinct line of division between them as might be expected if one was a deposit from water, and the other a rock that had been in such a state of pure igneous fusion as the slags of our furnaces or the erupted lavas. When the constituent minerals of solid granite, far from contact with the stratified rocks, are examined, it is seen that they also contain fluid-cavities. This is especially the case with the quartz of coarse-grained, highly quartzose granites, in which there are so many, that the proportion of a thousand millions in a cubic inch is not at all unusual; and the enclosed water constitutes from one to two per cent. of the volume of the quartz. However, besides these fluid-cavities, the felspar and quartz contain excellent stone-cavities, precisely analogous to those in the crystals of slag, or erupted lavas; and thus the characteristic structure of granite is seen to be the same as that of those minerals formed under aqueo-igneous conditions in the blocks which are ejected from modern volcanos; and the very common occurrence of minute crystals inside the fluid-cavities still further strengthens this analogy.

The conclusion to which these facts appear to lead, is that granite is not a *simple igneous rock*, like a furnace-slag, or erupted lava, but is rather an *aqueo-igneous rock*, produced by the combined influence of liquid water and igneous fusion, under similar physical conditions to those existing far below the surface at the base of modern volcanos.

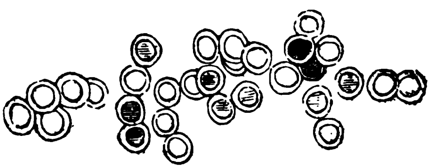
These deductions of the author, therefore, strongly confirm the views of Scrope, Scheerer, and Elie de Beaumont; and he agrees with them in considering it probable that the presence of the water during the consolidation of the granite was an instrumental, if not the actual cause of the difference between granite and erupted trachytic rocks.

B. *Page* 901.—LOGAN- OR ROCKING-STONES.—In that most successful of all the attempts to clothe science in the garb of fancy,—Dr. Paris's delightful volume called "*Philosophy in Sport made Science in Earnest*,"—there is an interesting account of the *rocking-stones* of Cornwall, which the antiquaries of the last century claimed as Druidical monuments, but which have originated in the natural causes explained in the following description of the celebrated Logan- or logging-stone, near the Land's End:—

"The foundation of this part of the coast of Cornwall is a stupendous group of granite rocks, which rise in pyramidal clusters to a great altitude, and overhang the sea. The celebrated Logan-stone is an immense block, weighing above sixty tons. The surface in contact with the under rock is of very small extent, and the whole mass is so nicely balanced, that, notwithstanding its magnitude, the strength of a single man applied to its under edge is sufficient to make it oscillate. It is the nature of granite to disintegrate into rhomboidal and tabular masses, which, by the further operation of air and moisture, gradually lose their solid angles, and approach the spheroidal form. The fact of the upper part of the cliff being more exposed to atmospheric agency than the parts beneath will sufficiently explain why these rounded masses so frequently rest on blocks which still preserve the tabular form; and since such *spheroidal* blocks must obviously rest in that position in which their lesser axes are perpendicular to the horizon, it is equally evident that, whenever an adequate force is applied, they must vibrate on their point of support." *Philosophy in Sport*, sixth edition, p. 465.

C. *Page* 918.—The Rev. J. B. Reade, F.R.S. &c., ON FOSSIL INFUSORIA IN MICA.

In a letter to the Author, in reply to an inquiry respecting the possibility of the existence of the organic structure in granite, the Rev. J. B. Reade, after referring to his previous observations on the indestructibility by heat of some of the silicious and calcareous structures of the higher plants (see p. 716), and pointing out that the silicious parts of the Diatomaceæ and of some of the Protozoa also retain their forms and characters after exposure to fire,—remarked as follows:—"My original inquiry having thus conducted me to the conclusion, that *silicious organization is not destructible by the agency of heat*, I thought it not unreasonable to infer that a careful and more extended microscopical examination into the condition of silica might lead to the discovery of elementary organic forms even in the primitive strata themselves. It was obviously not necessary to exclude granite from this examination, under the common and apparently natural impression, that the igneous fusion which preceded the present arrangement of its particles would destroy every trace of organization; for I had before me too many manifest proofs that an intense white heat, though capable of fusing glass, was incapable of effecting any change in the minute silicious organization both of plants and diatoms. Moreover there appeared to be a strong suspicion in some minds that every successive surface of our globe had been characterized by its own minute living forms; and you yourself had more than once contended for the existence of life during the granitic period. To give a reality, however, to a *first condition*, thus pronounced to be *probable*, we must discover silicious skeletons or shields even in granite itself. But here arises a difficulty which it will baffle our utmost ingenuity to remove; for, though, on the one hand, I met with silicious corpuscules in the primitive rocks, and find, on the other hand, that the indestructible

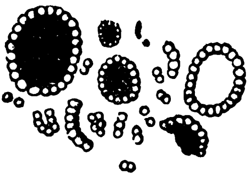


LIGN. 212.—MINUTE FLAT CIRCULAR BODIES IN MICA.

Corresponding in size and appearance with the rings of GALLIONELLA DISTANS.
Magnified about 500 times linear.

(Discovered and drawn by the Rev. J. B. Reade.)

organic skeletons of recent Infusoria exhibit, even under a power of 900 linear, a striking similarity of form, yet the entire absence of external structure precludes me from assigning a common origin to the ancient and recent organisms. Still, the inquiry, even in its present state, is far from being fruitless; for it cannot be a matter of surprise, that immense mountain-masses should have been found to consist of an aggregation of symmetrical bodies between $\frac{1}{1000}$ and $\frac{1}{800}$ of an inch in diameter, articulated together in the form of rings as in chalk (*Lign.* 212), or of slender threads, as in limestone and the quartz of granite, and that an exact counterpart of this curious structure in the mineral kingdom should be exhibited in the vegetable by the mouldiness of paste and the *Gallionella ferruginea*."



LIGN. 213.—The elementary molecules of Chalk, articulated in the form of rings, entire and in fragments. (*The Rev. J. B. Reade.*)

(Magnified about 500 diam.)

The Rev. J. B. Reade, in a courteous reply to the Editor's inquiry on some points of the interesting researches detailed above, states that—

"Some of the discoid-looking spots which I observed in granite might *possibly* have been the minute air- or water-cavities of Sorby (see p. 883); but those discovered in *mica* (and figured by Mantell) had too much the appearance of silicious organic structure to allow me to confound them with such cavities."

The *Lign.* 213 exhibits another interesting result of the Rev. Mr. Reade's microscopical researches in the minute structure of rocks, and was published in the first edition of the "Wonders of Geology." Although at first regarded as being illustrative of the occurrence of infusorial organisms in the chalk, these beaded, discoid, and ring-like bodies are more probably the result of the disintegration of the shells of Foraminifera (as Mr. H. C. Sorby has suggested in connexion with some of his own observations on the minute structure of limestones, &c.). Be this as it may, we cannot but hope that Mr. Reade, Mr. Sorby, Mr. Schafhault, Mr. Bryson, Prof. Ehrenberg, and others will continue their labours in "Microgeology" or "Clinology," as this branch of research has been termed; for it is a wide and promising field, but little cultivated as yet.

D. *Page* 992.—PARALLEL TERRACES OF GLEN ROY.—I am induced *to notice, in this place,* a remarkable phenomenon observable in of the glens of the Highlands that border the Great Caledonian Valley, because the subject has excited the attention of the tourist and the geologist. In several of the glens of Lochaber, but more especially in that of Glen Roy, there are parallel terraces, at various heights, extending on either side, and which present so regular and artificial an appearance as to have been ascribed to human art; and the ancient Highlanders supposed them to be roads formed by their hero Fingal.

The valley of Glen Roy is of an oval form, and is about four miles long, and one or more wide, being bounded on two opposite sides by high mountains. Through the middle of this valley, a river, formed by the confluence of some mountain-streams, flows into the Spean Water.

On each side of this long, hollow, deep valley, which is bounded by dark and lofty mountains, and at a great elevation, three strong lines are seen, parallel to each other and to the horizon; the levels of the opposite ones coinciding precisely with each other: and so striking is this symmetrical character, that the observer can with difficulty divest himself of the idea that he is contemplating some cyclopean work of the olden times. A slight examination of the nature of these parallel terraces is, however, sufficient to convince the instructed observer that they are probably the shores of an ancient lake, fed from the neighbouring Alpine regions, which at distant periods became shallower, and at length entirely disappeared, from the erosion of the barrier which formerly confined its waters.* The following explanation of the phenomenon is from a paper by Mr. D. Milne, which corroborates also the opinions of Professor Playfair and Dr. Macculloch:†—

The parallel shelves or terraces of Lochaber consist generally of bared rocks, forming sloping channels or water-courses; and they bear no accumulations of littoral deposits or detritus. They are perfectly horizontal, and are all coincident with some summit-level, so as to admit of the water flowing over that level as over a lip. Thus the uppermost shelf of Glen Gluoy is exactly coincident with the watershed-ridge which divides that glen from Glen Roy; so that

* On the Parallel Roads of Lochaber, by David Milne, Esq., Edinburgh New Philosophical Journal, October, 1847.

† See Dr. Macculloch, on the Parallel Roads of Glen Roy, Geological Transactions, *vol. iv. p.* 314; also Mr. Darwin, Phil. Trans. 1839, part 1, p. 39.

the waters which stood at that height must have flowed out at the head of Glen Gluoy into Glen Roy. In like manner the uppermost terrace in Glen Roy is coincident with the watershed-ridge dividing Glen Roy from the valley of the Spey: the waters which stood in Glen Roy, at the second level, must therefore have flowed over the head of the glen into Spey Valley. And the middle terrace of Glen Roy coincides with a watershed at the head of Glen Glaster. Ancient river-courses may be traced leading from the different levels of the terraces into the neighbouring glens and valleys of lower levels; and it seems evident that the waters which formed the several terraces flowed out of the glens, and descended by river-courses into the low countries. Thus the waters which formed the terrace in Glen Gluoy descended nearly thirty feet by flowing into Glen Roy; those of the upper shelf in Glen Roy flowed in like manner into the valley of the Spey; those of the middle terrace were discharged over the head of Glen Glaster down a slope of 212 feet in vertical height into Glen Spean; and the waters that produced the terrace or shelf in Glen Spean issued out of Lake Loggan by the ancient river-course at Mukkul.

It appears, therefore, that barriers originally existed, which pent up the waters at different levels in the glens, and were lowered at intervals; until at length the lakes were dried up, from the waters sinking from the level of the highest shelf to the next; and thus, by successive steps, as the barrier was worn away, the lowermost terrace was at length formed; and ultimately the system of lakes disappeared, from the barrier having been entirely removed.

E. *Page* 940.—MR. DARWIN, ON THE GALAPAGOS ARCHIPELAGO. —"This archipelago consists of ten principal islands, of which five exceed the others in size. The largest, Albemarle Island, is of an angular form, and 100 miles in length. They are all formed of volcanic rocks; a few fragments of granite, curiously glazed and altered by heat, can scarcely be considered as an exception. Some of the craters surmounting the larger islands are of immense size, and they rise to a height of between three and four thousand feet. Their flanks are studded by innumerable smaller orifices. I scarcely hesitate to affirm, that there must be in the whole archipelago at least two thousand craters: these consist either of lava and scoriæ, *or of finely-stratified* sandstone-like tuff. Most of the latter beautifully symmetrical; they owe their origin to eruptions of volcanic mud without any lava." A small jet of smoke was seen curling from one of the craters in Albemarle, and eruptions are known to have taken place in modern times.

Great parts of the surface of most of the islands are broken fields of black basaltic lava, thrown into the most rugged waves, and crossed by great fissures, and covered by stunted sun-burnt brushwood. But, while the lower parts of the islands are very sterile, the upper regions, at a height of a thousand feet, possess a damp climate and a tolerably luxuriant vegetation. The commonest bush is one of the Euphorbiaceæ, and, with an Acacia and a great odd-looking Cactus, are the only plants that afford any shade. Coarse grass and ferns abound in the upper parts, but no tree-ferns nor any of the Palm family were observed. Large land-tortoises, in prodigious numbers, are the principal animals, and form the staple article of food to the inhabitants, who are nearly all people of colour banished for political crimes from the republic of the Equator.

The rocks on the coast of Albemarle Island abound in great black lizards, between three and four feet long, belonging to two species; one of which is aquatic, and feeds on sea-weeds; the other is terrestrial. "They are allied to the Iguanidæ (?), and belong to the genus *Amblyrhynchus*, which is confined to this archipelago. They have long tails, flattened laterally, and all the four feet are partially webbed. Most of the other organic productions are found nowhere else: there is even a dissimilarity in those of the different islands; yet all show a marked relationship with those of America, though separated from that continent by an open space of ocean between 500 and 600 miles in width. Of terrestrial mammals, there is only one that can be considered as indigenous, namely, a mouse; and even this is confined to Chatham Island, the most easterly of the group. Of land-birds, twenty-six species were obtained, and all but one peculiar to these islands. Of the order of reptiles, in addition to the Amblyrhynchi, there are one small species of lizard of a South American genus, one snake, and of marine turtles, or chelonia, more than one species, and two or three of tortoises. No batrachian reptiles, as frogs or toads, were observed. The Amblyrhynchi are very abundant, and the terrestrial species especially in some places; in James's Island their burrows were so numerous, that it was difficult to find a spot free, on which to pitch a tent. The two species agree in their general structure, and in many of their habits; they have not that rapid movement so characteristic of the genera Lacerta and Iguana. They are both herbivorous, although the kind of vegetation on which they feed is very different; the land-species feed on the succulent Cactus, and the aquatic species on sea-weed. Mr. Bell has given the name to the genus from the shortness of the snout: indeed the form of the mouth may almost be compared to that of the tortoise: an adaptation probably referable to their herbivorous appetites. It is very interesting thus to find a well-characterized genus, having its marine and terrestrial species, belonging to so confined a portion of the world. The aquatic species is by far the most extraordinary, because it is the only existing lizard which lives on marine vegetable productions. These islands are not so remarkable for the number of the species of reptiles, as for that of the individuals. When we remember the well-beaten paths made by the thousands of huge tortoises,—the many turtles,—the great warrens of the terrestrial Amblyrhynchi,—and the groups of the marine species basking on the coast-rocks of every island in this archipelago,—we must admit that there is no other quarter of the world where the Order of Reptiles replaces the herbivorous mammalia in so extraordinary a manner. The geologist, on hearing this, will probably refer back his mind to the Secondary epochs, when saurians, some herbivorous, some carnivorous, and of dimensions comparable only with our existing whales, swarmed on the lands and in the seas. It is, therefore, worthy his especial observation, that this archipelago, instead of possessing a humid climate and rank vegetation, cannot be considered otherwise than extremely arid, and, for an equatorial climate, remarkably temperate. The botany is as peculiar as the zoology. Of flowering plants, 185 species were collected, of which 100 are new; that is, previously unknown to the botanist; and 40 cryptogamic species." Notwithstanding the length of this extract, the reader should refer to the original for many highly interesting particulars, and sagacious comments, which are here necessarily omitted.—*Mr. Darwin's Journal of a Voyage Round the World,* chap. xvii.

ADDENDA.

I. Elevation of the Land.—From the following statement it appears, that the slow upward movement of the land is in progress in other countries as well as in Scandinavia (see vol. i. p. 115).

"*Gradual rising of Newfoundland above the sea.*—The whole of the land in and about the neighbourhood of Conception Bay, very probably the whole island, is rising out of the ocean at a rate which promises, at no distant day, materially to affect, if not to render useless, many of the best harbours on the coast. At Port de Grave a series of observations have been made, which undeniably prove the rapid displacement of the sea-level in the vicinity. Several large flat rocks over which schooners might pass some thirty or forty years ago with the greatest facility are now approaching the surface, the waters being scarcely navigable for a skiff. At a place called the Cosh, at the head of Bay Roberts, upwards of a mile from the sea-shore, and at several feet above its level, covered with five or six feet of vegetable mould, there is a perfect beach, the stones being rounded, of a moderate size, and in all respects similar to those now found in the adjacent land washes."—*Newfoundland Times*, October, 1847.

In Sir Charles Lyell's admirable Lecture, "On the successive Changes of the Temple of Serapis" (delivered before the Royal Institution of Great Britain, March 7, 1856), we find so much valuable information on the subject of the elevation and subsidence of areas of land, that the following abstract (from the Roy. Instit. Notices) will be of great use to the student.

"The Temple of Serapis, near Naples, is, perhaps of all the structures raised by the hands of man, the one which affords most instruction to a geologist. It has not only undergone a wonderful succession of changes in past time, but is still undergoing changes of condition, so that it is ever a matter of fresh interest to learn *what* may be the present state of the temple, and to speculate on *what* next may happen to it. This edifice was exhumed in 1750, from a mixed deposit, extending for miles along the eastern shores of the Bay of Baiæ, and consisting partly of strata containing marine shells, with fragments of bricks, pottery, and sculpture, and partly of volcanic matter of subaërial origin. Various theories were proposed in the last century to explain the lithodomous perforations, and attached serpulæ, observed on the middle zone of the three erect marble columns now standing; some writers, and the celebrated Goethe among the rest, suggesting that a lagoon had once existed in the atrium, filled, during a temporary incursion of the sea, with salt water, and that marine mollusca and annelids flourished for years in this lagoon, at a height of 12 feet or more above the sea level. This hypothesis was advanced at a time when almost any amount of fluctuation in the level of the sea was thought more probable than the slightest alteration in the level of the solid land. In 1807, the architect Niccolini observed that the pavement of the temple was dry, except when a violent south wind was blowing; whereas, on revisiting the temple fifteen years later, he found the pavement covered by salt water twice every day at high tide. This induced him to make a series of measurements from year to year, first from 1822 to 1838, and afterwards from 1838 to 1845; from which he inferred that the sea was gaining annually upon the floor of the temple, at the rate of about one-third of an inch during the first period, and about three-fourths of an inch during the second. Mr. James Smith, of Jordan-hill, when he visited the temple in 1819, had remarked that the pavement was then dry, but that certain channels cut in it for draining off the waters of a hot spring were filled with sea-water. On his return, in 1845, he found the high-water mark to be 28 inches above the pavement, which, allowing a slight deduction on account of the tide, exhibited an average rise of about an inch annually. As these measurements are in accordance with others, made by Mr. Babbage in 1828, and by Professor James Forbes in 1826 and 1843, Mr. Smith believes his own conclusion to be nearest the truth, and attributes the difference between his average and that obtained by Niccolini (especially in the first set of measurements by the latter observer) to the rejection, by the Italian architect, of all the highest water-marks of each year, causing his mean to be below the true mean level of the sea. In 1852, Signor Arcangelo Scacchi, at the request of Sir Charles Lyell, visited the temple, and compared the depth of water on the pavement with its level as previously ascertained by himself in 1839, and found, after making allowance for the tide at the two periods, that the water had gained only 4½ inches in thirteen years, and was not so deep as when measured by MM. Niccolini and Smith, in 1845; from which he inferred, that after 1845, the downward movement of the land had ceased, and before 1852, had been converted into an upward movement. Since that period, no exact account of the level of the water seems to have been taken, or at least none which has been published.

"Sir Charles Lyell then called attention to the head of a statue, lent to him for exhibition by Mr. W. R. Hamilton, and which Mr. H. had purchased from a peasant at Puzzuoli, in the neighbourhood of the temple. This head bears all the distinctive marks of the Jupiter Serapis of the Vatican; and, among others, a flat space is seen on the crown, doubtless intended to receive the ornament, called the modius, or bushel, an emblem of fertility, which adorns the ancient representations of this deity. One side of the head is uninjured, as if it had lain in mud or sand, while the other has 'suffered a sea change,' having been drilled by small annelids, and covered with adhering serpulæ, as if submerged for years in salt water, like the three marble columns before mentioned.

"The speaker then alluded to an ancient mosaic pavement, found at the time of his examination of the temple, in 1828, five feet below the present floor, implying the existence of an older building before the second temple was erected. The latter is ascertained by inscriptions, found in the interior, to have been built at the close of the second and beginning of the third centuries of the Christian era.

"A brief chronological sketch was then given of the series of natural and historical events connected with the temple and the surrounding region; comprising the volcanic eruptions of Ischia, Monte Nuovo, and Vesuvius; the date of the first and second temples, and their original height above the sea; the periods of the submergence and emergence of the second temple; the nature of the submarine and supramarine formations, in which it was found buried in 1750; and, lastly, allusion was made to a bird's-eye view of this region, published at Rome in 1652, and cited by Mr. Smith, in which the three columns are represented as standing in a garden, at a considerable distance from the sea, and between them and the sea two churches, occupying ground which has since disappeared.

The history of the sinking and burying of the temple in the dark ages, respecting which no human records are extant, has been deduced from minute investigations made by Mr. Babbage and Sir Edmund Head, in 1828, respecting the nature and contents of certain deposits formed round the columns, below the zone of lithodomous perforations.

"The unequal amount of movement in the land and bed of the sea, and its different directions in adjoining areas in and around the Bay of Baiæ, were then pointed out; and the fact that the Temples of Neptune and the Nymphs are now under water, as well as some Roman roads, while no evidence of any corresponding subsidence or oscillations of level are discoverable on the site of the city of Naples, which is only four miles distant in a straight line. Analogous examples of upward and downward movements in other parts of the Mediterranean were cited, such as the sarcophagus of Telmessus in Lycia, described by Sir Charles Fellows; and the changes in Candia, recently established by Captain Spratt, R.N., who has ascertained that the western end of that island has been uplifted 17 feet above its ancient level, while another part of the southern coast has risen more than 27 feet, so that the docks of ancient Grecian ports are upraised, as well as limestone rocks drilled by lithodomi. At the same time the eastern portion of Candia (an island about 200 miles long) has sunk many feet, causing the ruins of several Greek towns to be visible under water. Looking beyond the limits of the Mediterranean, the buried Hindoo temple of Avantipura in Cashmere, with its 74 pillars, described by Dr. Thomson and Major Cunningham, were mentioned, and how their envelopment in lacustrine silt, at some period after the year 850 of our era, had caused them and their statues to escape the fury of the Mahometan conqueror Sicander, who bore the name of the idol-breaker. (*Principles of Geology, 9th edition*, p. 762.) The gradual subsidence of the coast of Greenland, and the elevation of a large part of Sweden, century after century, were also instanced; and lastly, the latest event of the kind, yielding to no other in the magnitude of its geological and geographical importance, the earthquake of New Zealand, of January 23rd, 1855. The shocks of this convulsion extended over an area of land and sea three times as large as the British Isles; after it had ceased, it was found that a tract of land, in the immediate vicinity of Wellington, comprising

4600 square miles, or nearly equal to Yorkshire in dimensions, had been upraised from one to nine feet, and a range of hills, consisting of older rocks, uplifted vertically, while the tertiary plains to the east of it remained unmoved; so that a precipice nine feet in perpendicular height was produced, and is even said to be traceable for 90 miles inland, from north to south, bordering the plain of the Wairarapa. In consequence of a rise of five feet of the land on the north side of Cook's Strait, near Wellington and Port Nicholson, the tide had been almost excluded from the River Hutt, while on the south side of the same straits in the Middle Island, where the ground has sunk about five feet, the tide now flows several miles further up the river Wairau than before the earthquake.

"Sir Charles then alluded to his discovery, in 1828, of marine shells in volcanic tuff, at the height of nearly 2000 feet, in the island of Ischia; and to the exact agreement of these, as well as other fossil shells, since collected by M. Philippi, with species now inhabiting the Mediterranean. If the antiquity of such elevated deposits, when contrasted with those found during the last 2000 years in the neighbourhood of the Temple of Serapis, be as great as the relative amount of movement in the two cases, or as 2000 is to 30 feet, it would show how slowly the testaceous fauna of the Mediterranean undergoes alteration: and therefore that naturalists ought not to expect to detect any sensible variation in the marine fauna in the course of a few centuries, or even several thousand years.

"In conclusion: the probable causes of the permanent upheaval and subsidence of land were considered—the expansion of solid rocks by heat, and their contraction when the temperature is lowered, the shrinkage of clay when baked, the excess in the volume of melted stone over the same materials when crystallized, or in a state of consolidation; and, lastly, the subterraneous intrusion of horizontal dykes of lava, such as may have been injected beneath the surface, when melted matter rose to the crater of Monte Nuovo, in 1538. A large coloured section of a cliff, 1000 feet high, at Cape Giram, in Madeira, was referred to as illustrating the intrusion both of oblique and horizontal dykes, between layers of volcanic materials previously accumulated above the level of the sea, and after Madeira had been already clothed with a vegetation very similar to that with which it is now covered. The intercalation of such horizontal sheets of lava between alternating beds of older lava and tuff would uplift the incumbent rocks, and form a permanent support to them; but when the fused mass cools and consolidates, a partial failure of support and subsidence would ensue."

II. Mastodon and Elephant.—So much light has of late been brought to bear on the history of these great pachyderms, both in a zoological and geological point of view, by Dr. Hugh Falconer, F.R.S., F.G.S., that we are induced to reproduce the Abstracts of his memoirs on the subject, read before the Geological Society of London; drawing attention particularly to the specific alliances of the remains of the Mastodon found in the Crag of Norfolk (see vol. i. p. 160), which Dr. Falconer determines to be the Auvergne species, and not that known as M. angustidens.

1. On the Species of Mastodon and Elephant occurring fossil in Great Britain.—Part I. Mastodons. By H. Falconer, M.D., F.R.S., F.G.S.

The object of this communication is to ascertain what are the species of the Proboscidea found fossil in Britain; what the specific names which ought to be applied to them; and what the principal formations and localities where they are elsewhere met with in Europe. The Mastodon of the Crag forms the subject of this first part of the memoir: the second part will treat of the Elephant-remains found in Britain. The author commenced by insisting on the importance to geology that every mammal found in the fossil state should be defined as regards, first, its specific distinctness; and, secondly, its range of existence geographically and in time, with as much severe exactitude as the available materials and the state of our knowledge will admit. He observed that with regard to the remains of the proboscidean genera, Dinotherium, Mastodon, and Elephant, some of which abound in the miocene and pliocene deposits of Europe, Asia, and America, the opinions respecting the species and their nomenclature, in all the standard palæontological works on the subject, are extremely unsettled and often contradictory.

Dr. Falconer then proceeded to explain his views of the natural classification of the proboscidean pachydermata, recent and fossil, according to dental characters. In the Dinothere, with its tapiroid molars, the last milk-molar and the antepenultimate (or first) true molar are invariably characterized by a "ternary-ridged-crown-*formula*," or in other words, their crowns are divided into 3 transverse ridges. In the Mastodon not only the last milk-molar and the first true molar, but also the second or penultimate true molar (being three teeth in immediate contiguity), are invariably characterized in both jaws by an isomerous division of the crown into either three or four ridges; or, in other words, are severally characterized by either a "ternary-" or "quaternary-ridge-formula." These three isomerous-ridged teeth are referred to as "the intermediate molars." To the ternary-ridged species the author assigns the subgeneric name of *Trilophodon*; and *Tetralophodon*, to the quaternary-ridged species. The molar in front, and that one behind these intermediate molars, are also characteristically modified in these two subgenera. In Trilophodon the penultimate or second milk-molar is two-ridged, and the last true molar is four-ridged: in Tetralophodon, the former is three-ridged, and the latter five-ridged. The author considers it highly probable that a subgeneric group characterized by a quinary-ridge formula (*Pentalophodon*) has existed in nature, but of which no remains have yet been discovered.

The Elephants are distinguished from the Mastodons by the absence of an isomerous ridge-formula, as regards the three intermediate molars, and by the ridges ranging from six up to an indefinite number in these teeth, in different groups of species. Dr. Falconer arranges the numerous fossil and recent forms in three natural subgenera, founded on the ridge-formula, in conjunction with other characters. In the *Stegodon* (comprising besides other forms the *Mastodon elephantoides*, Clift) the ridge-formula is hypisomerous; and the ridges number six or eight. The *Loxodon* (including the African Elephant) is also hypisomerous, and has from seven to nine plates or ridges. The *Euelephas* (including the *Elephas Indicus* and six fossil species) is the largest and most important group, and comprises the typical Elephants having thin-plated molars. Here the ridge-formula is anisomerous, and regulated by progressive increments, as 8, 12, 16; the higher its numerical expression, the greater the liability to vary, within certain limits dependent upon the race, sex, and size of the individual. The lower molars often exhibiting an excess of plates over those in the upper molars.

Reverting to the Mastodons, Dr. Falconer observed that the subgenera Trilophodon and Tetralophodon, as regards number of forms, are of nearly equal value; the former comprising seven, and the latter six, well-marked species. Each group is divisible into two parallel subordinate groups. In the one series the ridges are broad, transverse, more or less compressed into an edge; with the intermediate valleys open throughout, and entirely uninterrupted by subordinate tubercles. These are represented in Trilophodon by *Triloph. Ohioticus*, and in Tetralophodon by *Tetr. latidens*. In the other series the ridges are composed of blunt conical points, which are fewer in number, flanked in front and behind by one or more subordinate outlying tubercles, which disturb the transverse direction of the ridges and block up the valleys. This series is represented by *Trilophodon angustidens* and by *Tetralophodon arvernensis*. In both subgenera the species with transverse compressed ridges may be compared with Dinotherium, as regards their molar crowns; and the other series with Hippopotamus.

The European fossil species of *Mastodon*, according to the author, are the following:—*Trilophodon Borsoni*, I. Hays, *Tril. tapiroides*, Cuvier, *Tril. angustidens*, Cuvier (*pro parte*), *Tril. pyrenaicus*, Lartet MS., *Tetralophodon longirostris*, Kaup, and *Tetr. arvernensis*, Croizet and Jobert. With the exception of Triloph. Borsoni and Tetral. arvernensis, which are of Pliocene age, the above-named species are of Miocene age.

Dr. Falconer proceeded to state that the remains of only one species of Mastodon have hitherto been discovered in the British Isles. They occur in what is called the Older Pliocene Red Crag, at Felixstow and Sutton, in Suffolk, and in the Newer Pliocene Fluvio-marine or Mammaliferous Crag at various localities near Norwich and in Suffolk. After remarking that Professor Owen had referred the teeth of the Crag Mastodon to M. angustidens, making M. longirostris and M. arvernensis to be synonyms of this species (as Cuvier had also done), Dr. Falconer gave in detail the history of the discovery and publication of the true M. angustidens (Cuvier), and of the M. arvernensis and M. longirostris. He then passed in review the opinions and statements of these authors, as well as of Blainville, Laurillard, Gervais, Pomel, Lartet, and Sismonda, on these species, and on the specimens which these observers had severally described, sometimes under additional specific names. He then described the characteristic peculiarities both of the molars and of the symphysis of the lower jaws in these three species; and showed that the molars from the Crag were, like those of *Tetral. arvernensis*, characterized four-ridged molars, with their conical points more or less alte and with their valleys blocked up; and that they essentially differed from the molars of the *Triloph. angustidens* from Simorre, Dax, &c., and from the *Tetral. longirostris* of Eppelsheim. The M. arvernensis of Montpellier, Auvergne, Italy, &c., had no lower tusks; and the author is of opinion that the only specimen which has been figured and described as one of the lower tusks of the Crag Mastodon is a terminal fragment of one of the upper tusks of this species.

From osteological considerations it appears that Tetral. arvernensis was of a low and heavy make; that Tetral. longirostris was of similar general proportions; and that Triloph. angustidens was higher in its limbs and of a comparatively light and slender shape.

In his observations on the Geological age and associated faunas of the formations in which these species severally occur, Dr. Falconer observed that *Trilophodon angustidens* is a characteristic species of the miocene falunian beds throughout Europe, and is associated with *Triloph. tapiroides* in the Faluns of France and the upper freshwater Molasse of Switzerland. *Tetralophodon longirostris* is an important member of the Eppelsheim fauna, which, though its determination is accompanied with great difficulty, appears to be identical in its leading features with that of the falunian deposits of France and Switzerland. The *Tetralophodon arvernensis* is characteristic of the pliocene fauna; and it had a very extended range of habitat over Europe, accompanying *Loxodon meridionalis* (Nesti) in Tuscany,—*Trilophodon Borsoni, Loxodon priscus,* and *Euelephas antiquus* in Piedmont and Lombardy,—*Loxodon meridionalis* at Montpellier,—and *Tril. Borsoni, Lox. meridionalis,* and *Lox priscus* in Velay and Auvergne. After having reviewed the circumstances under which Mastodon remains occur in the British strata, Dr. Falconer concludes that,—1st, The Mastodon remains which have been met with in the Fluvio-marine and Red Crags belong to a pliocene form, namely *Tetralophodon arvernensis.* 2ndly, The mammalian fauna of the Red and Fluvio-marine Crags, regarded as a whole, bears all the characters of a Pliocene age, and is identical with the Subapennine Pliocene fauna of Italy. 3rdly, The Red and Fluvio-marine Crags, tested by their mammalian fauna, must be considered as beds of the same geological age.

Throughout this paper, for the sake of clearness, the subgeneric names have been used in designating the species. The author, finding that the name *Elasmodon*, applied to the third group of

Elephants, in the "Fauna Antiqua Sivalensis," in 1847, had been previously used for a fossil fish, has abandoned it, and applies the term *Euelephas* in lieu of it.

2. On the Species of Mastodon and Elephant occurring in the Fossil State in England.—Part II. Elephants. By H. Falconer, M.D., F.R.S., F.G.S.

In the introductory portion of Part I. of this Memoir, the author alluded to the ambiguity that has existed relative to the mammalian faunæ of the Miocene and Pliocene periods in consequence of palæontologists confounding several distinct forms of *Mastodon*, of different geological ages, under one name (*M. angustidens*); and on this occasion Dr. Falconer stated, that, in the application of the name *Elephas primigenius* (Mammoth) to a multitude of elephantine remains from various superficial and deep deposits, over a vast extent of territory, and of different ages, a similar, if not a greater, amount of error and confusion had arisen. In fact, at least half the habitable globe has been assigned to the Mammoth as his pasture-ground, if we were to accept the determinations of all those who have written on the remains of *Elephas primigenius*. The duration, too, of this nominal species in time is equally remarkable, so considered; since, as it has been quoted from the lower and the upper pliocene beds, as well as from the post-pliocene glacial gravels, it ought to have existed before the European area received its present geographical form, and indeed before the Alps, Apennines, and Pyrenees reached their present elevation. After noticing the difficulty met with by the geologist in the classification of the newer Tertiaries, on account of this ubiquitous presence of the Mammoth, the author proceeded to show that several species, belonging to two distinct subgenera, have been generally confounded under the name of *Elephas primigenius;* and that each had its limited range in geographical area and geological time. The present condition of the nomenclature of the subject, and the history of the established species of European fossil Elephants, namely, *Loxodon meridionalis*, *Loxodon priscus*, *Euelephas antiquus*, and *Euelephas primigenius*, preceded an explanation of the principles on which the species are determined, and a description of the dental characters by which the Elephants are divisible into sub-genera, —a succinct account of which was given in the former part of the Memoir (Geol. Journ. vol. xiii. p. 462). The "intermediate molars" in Elephants have never less than six divisions of the crown, and sometimes as many as eighteen. These molars do not all have an equal number of ridges: some Elephants have an augmentation of only one ridge to the crown of the penultimate of these molars; these are "hypisomerous," namely *Stegodon* and *Loxodon;* others, in which the number of the ridges progressively increases, are "anisomerous," and form a third natural group, namely the *Euelephas* or *Elephas* proper. The *Stegodon* has four species, fossil in India; and approaches the *Mastodon* in the form of the molars. The *Loxodon* includes the existing African Elephant and three fossil species, and is characterized by its distinct rhomboidal discs of wear on the grinders. *Euelephas* has thin-plated molars; but in some species there are intermediate stages, as regards the angular mesial expansion of the plates, between it and *Loxodon.*

Dr. Falconer next proceeded to review some well-ascertained mammalian faunæ localized in certain parts of Europe, where the conditions of deposit are most simple, and to apply the results to the more complex instances, where the remains of more than one distinct fauna are intermingled, or so closely deposited as to be too readily confused by collectors. With this view, the author instanced the Subapennine or pliocene deposits of the Astesan, and elsewhere in Piedmont and Lombardy, where *Trilophodon Borsoni, Tetralophodon arvernensis, Loxodon meridionalis, Lox. priscus,* and *Euelephas antiquus,* with *Rhinoceros leptorhinus, Hippopotamus major,* &c., are found associated together. In the Subapennine beds of the Val d'Arno, in Tuscany, *Tetralophodon arvernensis* and *Loxodon meridionalis* occur with the same *Hippopotamus* and *Rhinoceros.* Near Chartres in France, *Loxodon meridionalis* accompanies *H. major* and *Rhinoceros leptorhinus.* The above-mentioned are necessarily the leading mammalian forms of the older Pliocene period. North of the Alps pliocene deposits similar to those of Italy occur in some parts of Switzerland, but they are soon overlaid towards the north by a distinct mass of erratic drift of a different age and with different mammalian remains. In the fluviatile "Loess" or "Lehm" of the valley of the Rhine, and in the Glacial Drift of the plains of Northern Germany, these post-pliocene deposits contain remains of the true Mammoth, with the tichorhine Rhinoceros, the Musk-buffalo, &c., which thus constitute the leading types of the post-pliocene mammalian fauna.

On the eastern coast of England, the Crag-deposits (the Red and

Norwich Crags) yield the pliocene *Tetralophodon arvernensis*, *Loxodon meridionalis*, and *Euelephas antiquus*: and the so-called Elephant-beds at Cromer, Mundesley, and Hasborough furnish *Lox. meridionalis* and *Euel. antiquus*, with *Rhin. leptorhinus* and *Hip. major*. These characteristically pliocene fossils, however, are occasionally intermingled with the remains of the post-pliocene *Euelephas primigenius*, the latter fossils having been derived from the overlying and later drift-beds, which have thus proved a fertile source of the confusion and ambiguity already referred to. To some extent, similar conditions exist at Bracklesham Bay and Pagham Harbour, where molars of *E. primigenius* are found in the upper gravels, whilst remains of *E. antiquus* abound in the older mud-deposit, lately described in the Geological Society's Journal by Mr. Godwin-Austen.

Dr. Falconer then considered the fluviatile deposits of the Valley of the Thames, in relation to their Elephantine remains; especially at Grays Thurrock and Brentford. At the former place the author recognises the true pliocene assemblage of *Loxodon priscus*, *Euelephas antiquus*, *Hippopotamus major*, and *Rhinoceros leptorhinus*; but the group of mammals found at Brentford, according to the published determinations, indicate the close proximity of both the pliocene and post-pliocene faunæ at different levels of the same section. The Grays Thurrock deposits, and the lower beds at Brentford, were inferred to be of an earlier age than any part of the Boulder-Clay or Till.

The grouping of the *E. primigenius*, *Rhinoceros tichorhinus*, *Bubalus moschatus*, &c., in the newer gravels of England and elsewhere, was next dwelt upon, as affording an additional clue to the tracing of the several characteristic mammalian faunæ over the European area.

To the possible objection of there being too many large Proboscideans grouped in one fauna, the author replied that the bones of Elephantine animals of three distinct species actually occur together in one stratum in Italy, and that six species are found in deposits of one age in the Sivalik hills.

Dr. Falconer concludes that the same mammalian fauna existed throughout the period during which both the Crag and the fluviatile beds of the Thames Valley were being deposited; and that a chronological division of the newer Tertiaries into older Pliocene, newer Pliocene or Pleistocene, and Post-pliocene, is untenable; too much stress having been laid by authors upon the shell-evidence on this point. At the same time, it is not meant to be implied that all the species of the fauna ranged everywhere throughout the area; some in all probability were peculiar to the south, and others to the north.

The presence of the *Hippopotamus* in the pliocene deposits was pointed out as being of great importance in indicating the character of the pliocene land, which, extending between England and the Continent, must have afforded a great system of rivers and lakes, and probably had a comparatively warm temperature, as late as the deposition of the Grays bed, where also (as is well known) occur some southern freshwater shells, now extinct in England.

After some remarks on the negative evidence afforded by this mammalian fauna with regard to the supposed refrigeration of the land during the Pliocene period, Dr. Falconer reviewed the opinions of some English geologists on the physical conditions and faunæ of this region during the newer Tertiary epoch, especially the views of Mr. S. Wood, Mr. Prestwich, and Mr. Trimmer; and concluded with a few remarks on the occurrence of *E. antiquus* in the Cefn and Kirkdale Caves, and of *E. primigenius* in Kent's Hole, and on the non-existence of *E. primigenius* south of the Alps, and its restriction in the United States of America to the Northern and Central States. In the Southern States and in Mexico a distinct fossil species, *Euelephas Columbi*, hitherto undescribed, occurs along with remains of *Mastodon*, *Mylodon*, *Megatherium*, Horse, &c.

III. Possible extension of the Crag-deposits over a part of the South-east of England.—Some interesting, though not yet clearly explained, facts relative to certain tertiary beds overlying the Chalk of Kent, have been described by Mr. Prestwich, F.R.S., F.G.S., who thinks it probable that they may be of the age of the "Crag" (see vol. i. p. 223). To put our readers in possession of the main features of this discovery, the following abstract of Mr. Prestwich's Memoir is taken from the Quart. Journ. Geol. Soc. vol. xiii. p. 212.

On some Fossiliferous Ironstone occurring on the North Downs. By Joseph Prestwich, Esq. F.R.S., F.G.S.

Besides a drift of red loam with flints, and the few local outliers lower tertiary sands and pebble-beds, there are scattered on the summit of the North Downs from Folkestone to Dorking a few masses of sand, gravel, and ironstone, which present a certain regularity of structure and uniformity among themselves, and are clearly different from and of a later age than the outliers of eocene tertiaries on the same hills. Mr. Prestwich had long been acquainted with these ferruginous sands near Vigo Hill, where they are about 20 feet thick; and at Paddlesworth and other places near Folkestone, where they are even better developed; but, though the ironstone-fragments derived from these beds are frequently found dispersed about the Downs, it was long before he met with any fossils in these beds, with the exception of a piece of fossil wood pierced by *Teredo*, and an obscure cast of a bivalve shell, near Paddlesworth.

In December, 1854, however, some blocks of gritty ferruginous sandstone, full of casts of shells, were communicated to the author by Messrs. W. Harris and Rupert Jones, who had met with the specimens in some sandpipes in the Chalk at Lenham, eight miles east of Maidstone, and regarded them as belonging to the Basement Bed of the London Clay. This fossiliferous ironsand on close examination yielded casts of bivalve and univalve shells belonging to nearly thirty genera, besides indications of *Lunulites, Diadema*, &c. The presence of a *Terebratula* very like *T. grandis*, with several species of *Astarte*, and afterwards his finding a large Lutraria-like shell, led Mr. Prestwich to conclude that these sandy beds belonged to the Lower Crag. Mr. Searles Wood, to whom the fossils have been submitted, states that, as far as the evidence goes, he thinks they may be referred to the Upper Tertiaries, and in all probability to the Lower Crag period; the occurrence of a *Pyrula* and an *Emarginula* more especially strengthening this view.

Mr. Prestwich assigns without any doubt this shelly ironstone to the ferruginous sands above referred to, and points to the peculiar concentric arrangement of the contents of the sandpipes of the locality in question as definitely indicating (in accordance with the observations he formerly published in the Society's Journal *) the former existence of horizontal strata of—1. (lowermost) loam with flints,—2. greenish sands with ironstone-nodules,—3. yellow and reddish sands,—superposed on the bare chalk, after the eocene beds were for the most part denuded, and before the sandpipes were formed, into which these overlying beds were here and there let

* Vol. x. p. 64.

down, and thereby preserved when further denuding agencies removed the later tertiary beds.

Regarding then the outliers of ferruginous sands and sandstones above referred to as of the age of the Lower Crag, Mr. Prestwich pointed out the relative position of beds of similar structure, on the Downs between Calais and Boulogne, and on the top of Castle Hill near Dunkirk; and of others at Louvain, and at Diest in Belgium, mentioned by M. Dumont and Sir C. Lyell. This extensive range of Crag-beds to the south of the typical Suffolk area, and their considerable elevation above the sea, are of course matters of great interest, not only as pointing out the relative age of some of the drifts, but especially as giving us a still nearer date to limit the denudation of the Weald, and indicating marginal sea-beds now stretching far inland, and ranging once probably over the Wealden area,—possibly connected too with the Carentan beds of Normandy.

With regard to the denudation of the Weald, Mr. Prestwich suggests that, the anticlinal axis of the Weald having been somewhat raised during the cretaceous period, and the lower tertiaries partly constructed from its *débris* and gradually distributed over its area, it was again denuded to a further extent in the later tertiary period, some island or islands of the lower cretaceous rocks remaining in its area, from which for the most part these sandy ferruginous Crag-beds were derived. The great or final elevation and denudation of the Wealden area was necessarily subsequent to the deposition of these pliocene beds, for their outliers, resting on an old flint-drift, occur on the very edge of the upraised chalk-escarpments of the Weald. This elevation being also subsequent in time to the first or Lower Crag period, Mr. Prestwich suggests, that we have here evidence of the physical cause of the distinction of the two Crag periods. The first Crag sea was open to the south, and of considerable extent; but the last Wealden elevation, cutting off the southern portion, so altered the hydrographical conditions of the period, that a sea open only to the north remained, in which the Red or Upper Crag, with its partially boreal fauna, was then deposited.

IV. Extraneous fossils, pebbles, &c. in the Chalk.—The occurrence of pebbles foreign to the chalk-formation and other travelled fragments of rocks in the Chalk is comparatively rare, as stated at p. 487; but so interesting an exception to the rule was brought to light last summer, that the following abstract of Mr. Godwin-Austen's Memoir on the subject, read before the Geological Society, December 16, 1857, is here placed before the reader.

The boulder which, together with some associated fragments and sand, formed the subject of the communication, "On a Granitic Boulder out of the Chalk of Croydon, and on the Extraneous Rock-fragments found in the Chalk," by R. Godwin-Austen, Esq., F.R.S., F.G.S., was found by the workmen in a chalk-pit at Purley, about two miles south of Croydon. Mr. F. Simmonds drew the attention of Dr. Forbes Young to this interesting discovery, and the latter gentleman secured what remained of the boulder after it had been much broken up, and presented it to the Society. The largest remaining fragment is apparently one end of an irregularly oval well-rounded boulder, originally about 3 feet long, of a granitic rock, composed of quartz and felspar. The boulder was accompanied by some decomposing fragments of a felspathic trap-rock, and with a compact mass of silicious sand, which Mr. Godwin-Austen carefully exposed on a visit to the chalk-pit. This collocated mass of rock-fragments and sand the author regarded as being truly water-worn beach-material, derived from some old coast-line of crystalline rocks. Other smaller specimens of crystalline rocks, quartzites, &c., have been found in the Chalk of the South-east of England. These are all water-worn: some are quite rounded; and many of them bear the remains of attached shells and zoophytes: but they are nearly always isolated in position, except at Houghton (Sussex), where they were met with scattered over a uniform level.

The author proceeded to describe the conditions of the "marginal sea-belt,"—where pebbles are found in existing seas, and where also certain molluscs and zoophytes having habits of attachment occur. From such a marginal zone floating sea-weed might have borne the majority of the extraneous pebbles now found in the Chalk. Of this formation, the author observed that the "White Chalk" ranged as far north as a line reaching from the North of Ireland to Riga, on the Baltic, and extended in a broad zone over North Germany. In North Europe the conditions of the deposit were very uniform over the Anglo-French area, where 800 feet is its average thickness, and where it is of deep-water origin. Its fauna, however, is somewhat anomalous; much of it has drifted from shallower zones of *sea-bed. The littoral* or marginal shingles of the lower [illegible] series lie towards the west; that of the Lower Greensand is seen in the Farringdon Gravels; that of the Gault in the Halden Sands. The Chalk proper filled up the deeper and subsiding sea-bed at a period synchronous with the deposition of some of these littoral beds, and at the time of the greatest extension of the area of the Cretaceous Ocean, the littoral beds of which are recognisable in the South of Norway and Sweden, in Westphalia and Rhenish Prussia, &c., and the area of which probably may be regarded as reaching from the Rocky Mountains at the head of the Missouri, over Texas, Florida, the eastern side of the Alleghanies, the West Indies, and a broad belt of the Atlantic, to North Africa, Central and Northern Europe, with bold extensions into Western, Central, and even Eastern Asia. Central Europe then presented the aspect of a huge archipelago from its many extensive islands, of which one of the largest was an area comprising the chief part of France, the north-east of Britain, Ireland, Norway, Sweden, Lapland, and what are now the separating channels; together with a part of the Atlantic to the west and south. From the northern part of the old land-area the author believes that the granitic boulder of Croydon was derived. And, as it is, in his opinion, too massive to have been transported by floating trees, as Mr. C. Darwin describes an isolated rock-fragment to have been conveyed to the coral-islands of the Keeling group,—or by sea-weeds (the floating-powers of which the author has studied in the English Channel),—Mr. Godwin-Austen refers to an ice-floe as the agent by which such a block could alone have been lifted from the coast and conveyed far out to sea. The possible occurrence of rare and isolated boulders in the chalk-sea under such conditions was analogous, in Mr. Austen's opinion, to the occasionally extended voyage of icebergs at the present day to the coast of Ireland, the Azores, and even to the Madeira Islands.

[The large portion and several pieces of the granitic boulder and fragments of felspathic greenstone, from Croydon, presented by Dr. F. Young, are in the Geological Society's Museum; and several series of Pebbles, &c. from the Chalk, are in the Collections of the Rev. T. Wiltshire, F.G.S., W. Cunnington, Esq., F.G.S., W. Harris, Esq., F.G.S., J. S. Bowerbank, Esq., F.R.S., and H. Catt, Esq., and in the Society's Museum.]

GLOSSARY.

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nations of most of the scientific terms not included in this Glos- given in the text, and may be found by consulting the Index.

.. .. *headless;* molluscous animals without a head, as the Oyster, &c.

.. .. needle-like, sharp-pointed.

S .. .. *air-stones;* mineral masses that fall from the atmosphere.

.. .. a family of marine plants.

.. .. water-borne materials, especially river-deposits of recent formation.

US .. .. clayey.

M .. .. metallic base of clay.

.. .. sockets of the teeth.

US .. .. *shapeless;* devoid of regular form.

OID.. .. *almond-like;* cellular volcanic rocks, the cavities of which are filled with other substances.

SED .. branching and interlacing.

ED.. .. joints of bones immoveably united.

S .. .. animals having an external integument formed of rings; as the Worm.

.. .. the feelers of insects.

.. .. *flower-animals,* as the Actinia.

ITE.. .. stone-coal, or culm.

OTHERIUM an extinct animal, allied to the palæotheria, found in brown-coal.

.. .. *destitute of wings;* applied to a particular genus of bird.

ENT .. tree-like.

OUS.. .. sandy, or composed of sand.

EOUS .. clayey, or composed of clay.

TA.. .. animals without an internal skeleton, and having jointed coverings, as Insects.

ACEOUS .. plants of the reed-tribe.

.. .. shell-less mollusks, shaped like a bottle.

.. .. a genus of corals.

.. .. a dark-green mineral found in many volcanic rocks

S .. .. *pipe-scale* fish.

BARYTES .. .. heavy-spar; a mineral so called.
BASALT .. .. a lava, composed of augite and felspar; often columnar.
BASIN .. .. .. a series of deposits formed in a depression of older rocks, or bent up into a basin-like or trough-shaped form by subsequent movements.
BATRACHIAN .. .. animals analogous in structure to the frog; as the Salamander.
BELEMNITE .. .. (from *belemnon*, a dart), fossil internal shell of an extinct genus of cuttle-fish.
BIFID .. .. .. divided in two parts, or forked.
BILOBED .. .. divided into two lobes.
BITUMEN .. .. mineral pitch or tar.
BRACHIAL .. .. belonging to the arm.
BRACHIOPODA .. molluscous animals that have arm-like processes.
BRANCHIA .. .. aquatic organs of respiration, as gills.
BRECCIA .. .. conglomerate of fragments of rocks.
BRYOZOA .. .. *moss-animals;* a group of marine animals, as the Flustræ.

CALC-SINTER .. deposition from thermal springs charged with carbonate of lime.
CALCAIRE GROSSIER a tertiary limestone of the Paris basin.
CALCAREOUS .. .. composed of lime.
CALCIUM .. .. metallic base of lime.
CAMPANULARIA .. a bryozoan with bell-shaped cells.
CANCELLATED .. the cellular structure of a bone.
CAPSULE .. .. a little box or other containing cavity, a botanical term.
CARBON .. .. the elementary substance of charcoal, coal, and the diamond.
CARBONATE OF LIME lime and carbonic acid.
CARBONIFEROUS .. belonging to coal.
CARNEOUS .. .. fleshy.
CARYOPHYLLIA .. a clove-like coral.
CAUDAL .. .. belonging to the tail.
CENTRIFUGAL .. a force directed from the centre to the circumference.
CEPHALIC .. .. belonging to the head.
CEPHALOPODA .. animals having the instruments of motion placed around the head; as the Cuttle-fish.
CERVICAL .. .. belonging to the neck.
CETACEA .. .. marine mammalia, as the Whale, Porpoise, &c.
CHALCEDONY .. a species of silex, named from Chalcedon, a city of Asia, near which it is found in great abundance.
CHELÆ .. .. pincer-claws.
CHELONIA .. .. animals of the turtle tribe.
CHERT .. .. a silicious mineral allied to flint and chalcedony.
CHOANITE .. .. a zoophyte of the chalk.
CIRRHI .. .. curled processes, as in the Barnacle.
CILIA .. .. hair-like vibratory organs.

ED .. .. club-shaped.

GE .. .. the system of divisional planes in which crystals may be cleaved; the laminated structure in slate-rocks.

ERA .. .. insects having wing-cases, as Beetles.

DAL .. .. shell-like.

TION .. .. a coalition of separate particles.

E .. .. an articulating surface or joint.

MABLE .. applied to parallel strata lying upon each other.

MERATE .. pebbles or waterworn fragments cemented together, as in Puddingstone.

Æ .. .. trees bearing cones, as the Fir, Pine, &c.

RM .. .. heart-shaped.

ASH .. .. a coarse shelly limestone of the oolite.

FEROUS .. bark-bearing.

DONS .. .. seed-lobes of plants.

.. .. a term applied in Suffolk to certain tertiary beds of sand and shells.

.. .. the vent of a volcano.

IFORM .. having the form of a crater.

ATED .. notched, or toothed.

EOUS .. .. belonging to chalk.

EA .. .. lily-shaped animals.

T .. .. signifying the emergence of a stratum on the surface.

.. .. in form of a cross.

EA .. .. animals having an external crust or skeleton, as the Crab.

GAMIA .. plants with concealed fructification, as Mosses, Ferns, &c.

LLINE .. presenting the structure of crystals.

LS .. .. symmetrical forms assumed by mineral substances.

US .. .. coppery.

EROUS .. copper-bearing.

FORM .. cup-shaped.

CEÆ AND CY-
E .. .. a family of plants, including Zamia and Cycas.

(French) .. the ruins or detritus of rocks and strata, or the fragments of shells, &c.

OUS .. .. parts which are shed, as leaves of trees; botanically, having the habit of shedding.

.. .. alluvial deposits formed at the mouths of rivers.

TIC .. .. *tree-like;* branched like a tree.

TION .. the removal of strata by the action of water, so as to expose the rocks beneath, as in the Wealden of the S.E. of England.

.. .. belonging to the skin.

TION .. .. the act of drying.

US .. . disintegrated materials of rocks.

LEDONOUS .. plants with seeds having two lobes.

HIS .. .. a marsupial animal, allied to the opossum.

DILUVIUM .. . *deluge;* a term employed to designate ancient alluvial deposits.
DIP .. .. . the inclination of strata.
DIPTERA .. .. insects having two wings.
DISCOIDAL .. .. in the form of a disk.
DOLOMITE .. .. crystalline magnesian limestone.
DRUSES .. .. the cavities in minerals, lined with minute crystals; as, for example, *drusy-quartz* in the hollows of flint-nodules.
DYKE .. .. .. an intruded vein of melted matter into rents or fissures of rocks.

EARTH'S CRUST .. that portion of the solid surface of the earth which is accessible to human observation.
ECHINODERMATA .. animals having a prickly external integument, as the Starfish, Sea-Urchin, &c.
ECHINUS .. .. sea-urchin.
EDENTULOUS .. .. *toothless;* animals having no front teeth, as the Armadillo.
ELYTRA .. .. wing-cases of insects.
ENCRINUS .. .. a genus of lily-shaped animals.
ENTOMOSTRACA .. a large family of the crustaceans, including the Trilobites, Cyprides, &c.
EOCENE .. .. *dawn of the recent* period; the early tertiary strata.
EPHEMERON .. .. the creature of a day.
ERODED .. .. worn away.
ESCARPMENT .. .. a steep side of a hill or mountain-chain.
EXUVIÆ .. .. sheddings of animals and plants, or their relics.

FAULT .. .. interruption of the continuity of strata with displacement.
FALUN .. .. a French term for tertiary strata analogous to the Crag.
FAUNA .. .. the zoology of a particular country.
FELSPAR .. .. a mineral which enters into the composition of many crystalline rocks.
FELSPATHIC .. .. belonging to or composed of felspar.
FERRUGINOUS .. impregnated with iron.
FLORA .. .. the botany of a particular country.
FLUVIATILE .. .. belonging to a river.
FLUVIO-MARINE .. partly of fluviatile, and partly of marine origin.
FOLIACEOUS .. .. leaf-like or leafy.
FORAMINIFERA .. a division of animalcules having perforated shells.
FORMATION .. .. a group, or series of strata, supposed to have been formed during one geological period.
FOSSILIFEROUS .. fossil-bearing.
FUSIFORM .. .. spindle-shaped.

GASTEROPODA .. mollusks with the locomotive organs on the under-part of the body, as the Snail.
GELATINOUS .. .. jelly-like.

OSE .. .. globe-like.
ONIA .. .. a genus of flexible arborescent corals.
LÆ .. .. *stilts;* applied to birds having long legs and feet, like the Heron.
INACEÆ AND
AMINEÆ .. the order of plants comprising the grasses.
ULES .. .. little grains.
NSAND (upper
l lower) .. .. members of the chalk-formation.
NSTONE .. .. an ancient volcanic rock.
WACKE .. .. hard gritty rock, more or less metamorphic.
.. .. .. coarse sandstone.
UM . .. sulphate of lime.

PTERA .. .. insects with wings half horny and half membraneous.
BIVOROUS .. animals that eat herbs, as cattle.
OPTYCHIUS .. *allwrinkle* fish, in allusion to the corrugated scales.
ALONOTUS .. *smooth-back;* name applied to a genus of trilobites, in which the lobes are but feebly produced.
OLOGUE .. .. the analogous organ in different animals.
LINE .. .. of a glassy or crystalline appearance, or pellucid.
RA .. .. freshwater polype.
ROZOA .. .. coral-polypes organized like the Hydra.
ENOPTERA .. insects with four membranous wings.
OGENE .. .. rocks formed in the interior of the earth, as Granite.

ERGS .. .. floating masses of ice.
NA .. .. a lizard of the West Indies.
ICATED .. .. laid over each other like scales or tiles.
NDESCENT .. applied to mineral masses in a state of intense fusion.
CTION .. .. the derivation of principles from facts.
SORIA .. .. microscopic animals that abound in infusions.
CTIVOROUS .. animals that live on insects, as the Hedgehog.
SSATED .. .. dried up.
RTEBRATA .. animals without a bony spine or vertebræ, as worms, lobsters, &c.

STRINE .. .. belonging to a lake.
LLATED .. formed of, or covered with, thin plates or scales.
LLIFORM .. shaped like a thin plate or scale.
NÆ .. .. *thin plates;* the thin layers of which a stratum is composed.
LI .. .. a variety of volcanic ashes.
A .. .. the first stage of an insect.
.. .. .. melted mineral matter erupted from volcanos.
OPTERA .. insects having scaly wings, as Moths.
.. .. .. a provincial term, applied to a group of strata situated between the new red sandstone and the oolite.
TE .. .. carbonized wood.

LITHODOMI	mollusca which perforate stones, shells, &c.
LITHOLOGICAL ..	the stony character of a mineral mass.
LITHOPHYTES ..	*stone-plants;* a term applied to corals.
LITTORAL	belonging to the sea-shore.
LOESS	a tertiary deposit in the valley of the Rhine.
LYCOPODIACEÆ ..	the family of club-mosses.
MACRURA	*long-tailed* crustaceans, as the Lobster.
MACROPOMA	*long-operculum;* name of a fossil fish.
MAMMALIA OR MAMMIFERA	animals which give suck to their young.
MAMMILLATED ..	studded with mammillæ or rounded protuberances.
MANDIBLES	jaws.
MANTLE	the soft body-envelope of the mollusks.
MARL	a mixture of lime and clay.
MARSUPIALIA ..	animals which carry their young in a pouch, as the Kangaroo.
MATRIX	*womb;* the substance in which a mineral or a fossil is imbedded.
MEDULLARY	*marrow-like;* a term applied to the central pith in plants, and to the matter of the brain and spinal cord in animals.
METAMORPHIC OR METAMORPHOSED	altered rocks, such as clay-slate, quartzite, gneissose schist, &c.
METAMORPHISM OR METAMORPHOSIS	the change induced in strata by being subjected to pressure and high temperature.
MICA	a simple mineral, one of the component parts of granite.
MICACEOUS	containing mica.
MIOCENE	middle tertiary series.
MOLARES	grinding teeth.
MOLECULES	microscopic particles.
MOLLUSCA	soft animals, destitute of a bony structure, as Mussels, Snails, &c.
MONADS	the minutest infusorial animalcules.
MONITOR	a genus of lizards inhabiting the tropics.
MONOCOTYLEDONOUS	plants having seeds with but one lobe, as *Wheat.*
MORAINE	an accumulation of debris formed in valleys by glaciers.
MULTILOCULAR ..	many-chambered shells, as the Nautilus.
MULTIVALVE ..	shells composed of many pieces, as the Chiton.
MUSCHELKALK ..	*shell-limestone* of the Triassic series.
NACREOUS	pearly.
NEUROPTERA ..	insects having wings finely nerved, as the Dragon-fly.
NODULE	a rounded mineral mass, as a chalk-flint.
NORMAL	natural or regular condition.
NUCLEUS	a kernel or point round which other materials collect.
OBSIDIAN	glassy lava.
OCCIPUT	the back part of the skull.

OOLITE	limestone composed of an aggregation of spheroidal particles.
OPERCULUM	*a lid;* applied to the gill-covering in fishes, and the plate that closes the aperture in some univalve shells.
OPHIDIA	the snake tribe.
ORNITHORHYNCHUS	*bird-beak;* a genus of animals having the mouth produced into a beak like a bird.
OSSICULA	small bones.
OVATE	egg-shaped.
OVIPAROUS	animals which bring forth eggs.
OUTLIER	a detached or isolated mass of strata.
OXIDE	the combination of oxygen with any metallic substance.
PACHYDERMATA	thick-skinned animals, as the rhinoceros, elephant, &c.
PALÆONTOLOGY	the science which treats of extinct animals and vegetables.
PARIETES	the walls of the cavities in animals.
PECTINATED	toothed like a comb.
PEDIFORM	shaped like a foot.
PEDUNCLE	a stalk or support.
PELAGIC OR PELAGIAN	belonging to deep seas.
PEPERINO	a volcanic conglomerate or tuff.
PETROLEUM	*stone-oil;* mineral-oil.
PINNATE	shaped like a feather or fin.
PISOLITE	*pea-stone;* resembling peas agglutinated together.
PLEXUS	a bundle of vessels.
PLIOCENE	the newer groups of the tertiary formation.
PLUMOSE	feather like
POLYPIFERA	*polyp-bearing;* corals.
PORPHYRY	an ancient igneous rock.
POZZUOLANA	a variety of volcanic ashes used for making cement.
PRECIPITATE	the chemical separation, and deposit in a solid form, of a substance held in solution by water.
PROTOZOA	*first animals;* the lowest or simplest animals, such as Sponges, Foraminifera, &c.
PTYCHODUS	*wrinkle-tooth* fish.
PUMICE	light, spongy, or porous lava.
PYRIFORM	pear-shaped.
PYRITES	sulphide or bisulphuret of iron.
PYROGENOUS	*fire-born;* igneous, applied to ancient melted rocks.
QUADRUMANA	*four-handed;* the monkey tribe.
QUÂ-QUÂ-VERSAL	applied to concentric strata, that dip on every side.
QUARTZ	a mineral composed of pure flint.
QUARTZOSE	rocks composed of silex or flint.
RADIATA	one of the lower divisions of the ani... including the Corals, Echin...

RAMOSE .. .. branched.
RENIFORM .. .. kidney-shaped.
RETICULATED .. resembling net-work.
RODENTIA .. .. *gnawers;* an order of animals having teeth o peculiar structure, by which they can gnaw ho as the Rat, Squirrel, &c.
RUBBLE .. .. beds of fragmentary stone.
RUMINANTIA .. animals that chew the cud, as the Deer, Ox, &

SAURIANS .. .. reptiles of the lizard order.
SAURO-BATRACHIANS extinct reptiles that partook of the characters t of lizards and frogs.
SCAPHITE .. .. extinct genus of cephalopods, of a boat-like for
SCHIST .. .. hard laminated and shivery rock
SCORIÆ .. .. volcanic cinders.
SEDIMENTARY .. deposited as a sediment by water.
SEGREGATION .. a chemical separation of mineral substances
SEPTA .. .. partitions, as in the shells of the Nautili.
SEPTARIA .. .. indurated nodules of clay, having crevices fi with spar
SERRATED .. .. toothed like a saw.
SERTULARIA .. .. a genus of arborescent corals.
SHALE .. .. laminated clay.
SILEX .. .. .. flint.
SILICON .. .. the base of flint.
SILICIOUS .. .. flinty.
SILICIFIED .. .. changed into flint.
SILT .. .. .. fluviatile or marine mud.
SINTER .. .. a precipitate from mineral springs.
SPATANGUS .. .. a genus of sea-urchins.
SPATHOSE .. .. sparry, blade-like.
SPHEROIDAL .. .. oblate, or having the form of a spheroid.
SPICULA .. .. pointed pin-like particles.
SQUAMOUS .. .. scaly.
STALACTITE .. .. pendent masses of carbonate of lime or other neral.
STALAGMITE .. .. calcareous concretions formed on the floor of by droppings from the roof.
STELLULAR .. .. having star-like forms.
STERNAL .. .. relating to the sternum or chest.
STERNUM .. .. the breast-bone.
STRATIFIED .. .. deposited in layers.
STRATUM .. .. a layer of any deposit.
STRIKE .. .. the direction or line of bearing of strata, whi always at right angles with the dip.
STUFAS .. .. volcanic vents emitting gases and vapours.
SYENITE .. .. a species of granite in which *hornblende* su the place of *mica*.

TENTACULA .. .. feelers.
TERTIARY .. .. geological formations newer than the chalk.

A .. .. shell-fish; molluscs.

.. .. hot.

.. .. belonging to the chest or thorax.

E .. .. a variety of lava chiefly composed of felspar.

KS .. .. ancient volcanic rocks; the term derived from the Swedish, *trappa*, a stair.

INE .. .. crystalline tufaceous limestone.

D .. .. having three points.

YLE .. .. three-fingered.

TE .. .. three-lobed.

ES .. .. an extinct family of crustacea, the body divided into three lobes.

A .. .. organ-pipe coral; corals composed of tubes.

TUFF .. a porous calcareous deposit from incrusting streams; and an earthy volcanic rock.

TED .. top-shaped, in form of an inverted cone.

RMABLE .. strata lying in a different position to those on which they rest.

A .. .. hoofed animals.

E .. .. shell composed of but one piece.

.. .. fissures in rocks, filled up by mineral substances.

.. .. worms.

RM .. .. worm-shaped.

ATED .. animals having an osseous spinal column of vertebræ.

LATE .. arranged in whorls.

R .. .. full of vesicles or cells.

.. .. processes in animal structures, resembling the pile of velvet.

ATION .. the fusion of a substance into glass by heat.

US .. .. bringing forth live young.

.. .. *froth-stone;* peculiar minerals found in volcanic rocks.

.. .. the study of animals.

AL .. .. relating to animals.

ES .. .. *animal-plants*, a term applied to corals and other animals that resemble vegetables in form.

CORRIGENDA.—VOL. I.

Page viii. lines 3 and 8 from bottom; *for* Holæosaurus *read* Hylæosaurus
— 117, — 7 ———— *for* Puzzuo *read* Puzzuoli.
— 146, *for* LIGN. 23, *read* LIGN. 23*.
— 153, *for* LIGN. 24, *read* LIGN. 24*.
— 158, *for* LIGN. 25, *read* LIGN. 25*.
— 160, line 23 from top; *for* Mastodon angustidens (narrow tooth) *read* Mastodon Arvernensis (of Auvergne).
— 185, in the note; *for* Phocene, *read* Pliocene.
— 206, in the note; *for* *γινομα* *read* *γινομαι*.
— 332, line 14, *for* Cristallaria *read* Cristellaria.
— 334, bottom line; *for* Cotallines *read* Corallines.
— 376, in the note; *for* Brown *read* Bronn.
— 405, in the note; *before* composed *read* partly.
— 429, line 11 from top; *for* spine *read* joint.
— 433, in the note; *for* 1841 *read* 1839—1841.
— 440, line 23 from top; *for* tooth-ivory *read* ivory.
pl. vi., opposite p. 480, *for* 4½ inches *read* 4½ *feet*.

VOL. II.

Page 486, line 11 from bottom; *dele* the asterisk.
— —— in the note; *for* Rev. C. Fisher *read* Rev. O. Fisher.
— 487, in the note; *for* Henry Carr, Esq., *read* Henry Catt, Esq.
— 494, line 12 from top; *for* Himalay as *read* Himalayas.
— 774, in the note; *for* were *read* are to be.
— 873, in the note; *for* Lurullo *read* Jurullo.
— 906, line 5 from bottom, and p. 909 in the note; *for* Beauerel *read* Becquerel.

DIRECTIONS TO THE BINDER.

*** The Engraving of the Country of the Iguanodon is to front the Title-Page of Vol. I.

The Geological Map of England, *Plate* I. to be placed opposite to p. 474, Vol. I.

Plates II. III. and IV. to face their respective descriptions in Vol. I.; Plates V. and VI. to be placed at the end of Vol. II., opposite to p. 985 and p. 986.


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LIVING ZOOPHYTES AND BRYOZOANS; LECTURE VI.

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2. *Campanularia gelatinosa*; a branch highly magnified; some of the polypes are protruded, and others within their cells; p. 621.

3. *Gorgonia patula*; magnified view of a branch, with six polypes expanded; p. 628.

4 The coral of *Caryophyllia fasciculata*; p. 624.

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